Compendium of Smart Sugar Practices

A summary of well-established best practices for profitability and sustainability in Australia's tropical sugar cane industry

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Executive summary

The aims of this project were to:

- ✓ Provide documented evidence about profitable cane farming practices to improve water quality that are suitable to each Great Barrier Reef growing region and enterprises in a manner that enhances grower choices and opportunities
- ✓ Collate and synthesise existing evidence on the water quality, productivity and profitability impacts of these cane farming practices as the basis upon which to present and assess cane farming practices across the tropical catchments in the first instance and, potentially, Australia-wide.

In brief, the project has documented a series of smart practices in each of the four key Great Barrier Reef-related sugar growing regions – Mackay Whitsunday, Burdekin, Herbert River and Wet Tropics. Practices are grouped in four broad categories:

1. **Cropping systems** – integrated practices that deliver profitability and sustainability across the environmental concerns of nutrient, weed and herbicide and soil and water management while simultaneously delivering to profitability agendas such as reduced labour costs, maximum production outputs, minimal cost inputs and flexibility so that risks such as variable weather can be accommodated through tactical on-farm activities.
2. **Soil and water management** – practices such as water use efficiency that minimise negative risks to production and profitability while simultaneously providing maximum insurance against adverse environmental impacts off farm.
3. **Nutrient management** – practices that maximise plant uptake of nutrients towards highest possible productivity while minimising the likelihood of nutrient losses off farm.
4. **Weed management** – practices that minimise the cost of inputs such as chemicals and labour, maximise production by reducing plant competition and minimise the likelihood of chemical losses off farm.

For each region there are about 10 or 11 recognised smart practices across these categories. All these practices deliver enhanced profitability outcomes and are above the level of practices stated under legislation. The report concludes with suggested criteria for successful extension delivery, a list of key knowledge gaps and some observations on what activities might best continue the rapid rate of uptake of improved practices as has occurred in the previous four years under the *Reef Rescue* incentives funding.

About this project

The Reef Water Quality Program, part of the Queensland and Australian Governments' Reef Water Quality Protection Plan (Reef Plan), aims to reduce pesticide, fertiliser and soil runoff from cane farms by promoting the adoption of management practices that are well documented as having both profitability and water quality benefits, and that can be easily and cheaply adopted by the majority of growers.

As part of the Queensland Government commitment to Reef Plan, the Reef Water Quality Program's research and development program within the Department of Environment and Heritage Protection funded this research report, as one of suite of reports that invests in sharing and improving the knowledge base in understanding cost-effective management practices that are applicable to the cane industry. This will inform activity under Action 4 of Reef Plan 2009 which focuses *on identifying and updating information on improved land management practices to maximise water quality improvements.*

This report was developed by regional industry experts in consultation with their peers to identify the smart practices for the Wet Tropics, Herbert, Burdekin Dry Tropics and Mackay Whitsundays (Central Region), recognising that regional differences and socio-cultural characteristics will see some practices being better and easier to adopt in some regions than others.

The contribution of leading regional cane experts and researchers in the development of this report is gratefully acknowledged.

Generally the Reef Water Quality Program has focused on enhancing cane farm production and profitability whilst minimising losses of nitrogen, phosphorus and Photosystem II (PSII) pesticides from cane farms. This includes addressing aspects of optimising nutrients and herbicide rates for crop production. Low cost management options such as timing of application, irrigation management and fine tuning cropping systems to the weather will help keep nutrients and pesticides on farm. It always remains a farmer's decision as to whether practices are implemented that require additional investment, such as purchase of equipment to improve overall crop production, profitability and sustainability. Therefore, this report highlights any issues relating to farm infrastructure and capacity for each of the practices suggested.

The aim overall is to improve efficiency by reducing nutrients and herbicide inputs (and hence input costs) for crop production and improve the effectiveness of those inputs, at the same time as reducing losses. This should result in better water quality entering the Reef lagoon improving Reef health, coastal and marine ecosystems and fisheries.

As new information becomes available, this report will require updating. Likewise, government policy will be adapted to take account of new information. The report is provided in good faith, on the understanding that the information is not used out of the context explained within this guide to smart practice options.

Contents

Acronyms used in this document	**Name**
BSES	BSES Ltd (formally Bureau of Sugar Experiment Stations)
DAFF	Department of Agriculture, Fisheries and Forestry (previously DEEDI)
DEEDI	Department of Department of Department of Employment, Economic Development and Innovation
EHP	Department of Environment and Heritage Protection
EVTA	Effective Vegetated Treatment Area
GBR	Great Barrier Reef
NRM	Queensland Regional Natural Resource Management Program
PSII	Photosystem II
SRDC	Sugar Research and Development Corporation

Chapter 1: Introduction and methods

1.1 Background

This project principally came about because of the multiple activities in research and adoption of improved practices underway, and the plethora of farmer-led innovations providing a diversity of opportunities for the sugar industry. Documenting some of these smart practices will assist the sugar industry as it faces the joint challenges of enhanced profitability and sustainability.

In capturing the richness and variety of these practices, it was particularly important to make sure that the practices are documented in summary form. The task was to present the information in a format and content that can easily be reviewed by farmers for their applicability to their farm conditions. Farm conditions here refer to not only the biophysical environments but also the social settings, the farmer skills and equipment available and the farm business model.

1.2 The project in brief

This project will synthesise available information identifying practice options that can be easily and cheaply adopted by the majority of growers for improving both their profitability and the quality of water in runoff from cane farms in the Great Barrier Reef catchments – Wet Tropics, Herbert, Burdekin Dry Tropics and Mackay Whitsunday.

The report will, by being regionally based, ensure each set of practice opportunities are regionally relevant, and will:

- form the basis of regional advice on best practice options for cane growers around water quality improvement
- identify the level of certainty of benefits from both profitability and sustainability perspectives
- identify priorities for extension and demonstration activities that will foster increased rates of adoption
- suggest gaps in knowledge as part of the assessment of priorities for further R&D investment
- contribute to the reassessment of the role of regulations and the priorities for Reef Plan.

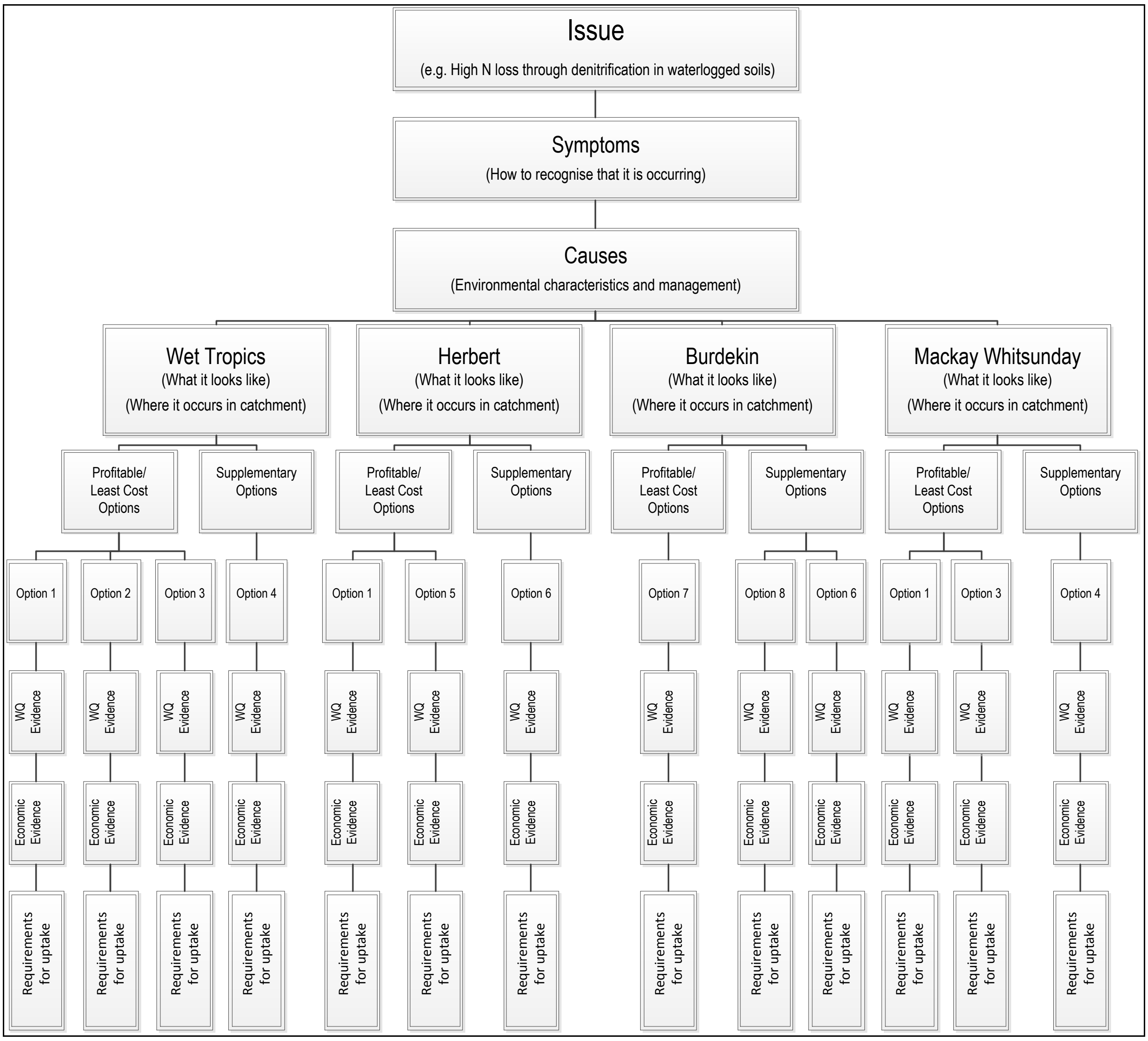
1.3 Information synthesis

As illustrated in Figure 1, the report will address specific cane management issues that occur in each of the regions and collate information in the following broad format:

1. By virtue of being undertaken as part of a cropping system, the smart practices will in many cases deliver benefits across multiple issues (e.g. soil and water management, nutrient management, weed management)

2. The practice – using the terminology used in each region and a summary description of the practice
3. The agronomic benefits of the practice, its likely profitability benefits and the certainty to which this profitability improvement has been documented
4. The water quality and overall sustainability benefits, again including the certainty to which this sustainability improvement has been documented
5. Minimum requirements needed for the practice option to be successfully adopted and any perceived impediments or issues that must be addressed in implementing the practice. These may include resource and equipment requirements, any regional / milling area specific issues and any social-economics constraints such as labour availability and skills
6. Supporting information, including published papers, handbooks and extension materials that provide further information on the practice.

Figure 1. Structure of information presentation



The final product will be a report that can be readily summarised into regionally specific, plain English extension materials for use by landholders and their extension providers, with the aim of supporting the selection of practice options that address an issue and suits their particular management preferences, available (or to be acquired) resources, property configuration and environmental conditions.

1.4 Overview of methods

The project was undertaken in the following phases:

- *Phase 1 – Information collation and collaboration* – collecting background information, linking with companion projects and establishing the key personnel across the cane industry that could contribute to the project
- *Phase 2 – Detailed project design* – documenting methods and processes to the agreement of the then Department of Environment and Resource Management and key industry members
- *Phase 3 – Smart practice documentation and regional review* – teams under regional leadership prepared the regional suites of practices and discussed and reviewed these with farmers, industry bodies, scientists and NRM groups in their region
- *Phase 4 – GBR wide collation and review* – all regional reports were widely disseminated, discussed and reviewed, including a workshop that bought together the key players in the sugar industry across all regions to review each regional report and agree on the priority directions for extension, R&D and adoption
- *Phase 5 – Final reporting* - all information and inputs were pulled together into this report.

1.5 This project and reef protection objectives

This project contributes to reef protection objectives by identifying best-bet (no-cost and least-cost) practice options for reducing nutrients, pesticides and sediment in runoff from cane farms while improving profitability. Effective communication of these practice options will support efforts to increase adoption of best practice for water quality improvement and most importantly, foster practices that go well beyond the Reef Water Quality Program's requirements.

The following is the list of Reef Water Quality research and development questions that this project will contribute to:

25a. Which cane management systems generate the least reef pollutants?

26a. What is the potential to reduce weed pressure and use of PSII pesticides using (1) non-PSII pesticides or non pesticide treatments, (2) integrated weed management at the property scale, (3) collaborative catchment-wide/mill district management and (4) technological innovation?

27d. Which cane management systems lead to the most efficient use of N & P fertilisers (minimum loss/unit of production)?

28a. What are the options for managing cane and associated crops to minimise erosion of damaging sediment fractions?

In doing so, it will also cover knowledge associated with the following questions:

6a. Why do some cane growers manage impacts significantly more profitably than comparable cane growers?

8a. What changes in systems and practices will be most cost effective at reducing loss of PSII to waterways from cane farms?

9a. What changes in systems and practices will be most cost effective at reducing loss of N and P to waterways from cane farms?

10a. What changes in systems and practices will be most cost effective at reducing loss of sediment to waterways from cane farms?

13a. Which regulated landscapes, sub-catchments and catchments under cane are the most susceptible to investment in system/practice change to achieve the most cost efficient reduction in PSII pesticides reaching the reef in the least time?

17a. What are the costs and benefits of preventive weed control?

17b. What are the costs and benefits of cane farm management systems that minimise the use and loss of PSII pesticides?

17c. What are the costs and benefits of cane farm management options that optimise the use and minimise the loss of N and P?

17d. What are the costs and benefits of cane farm management options that cause the least erosion of damaging sediment fractions?

17e. What are the costs and benefits of efficient mill mud application on the farm at the mill?

19a. What are the characteristics of land managers that influence their management decisions (e.g. demography, property ownership, training and educational experience, level of economic independence)?

19b. What are the critical factors influencing managers in adopting reef-friendly practices 1. That they know will improve short term profitability, 2. That they are told will improve short term profitability?

25b. What are the most effective methods for trapping loss of reef pollutants from cane farms (e.g. EVTAs)?

27a. What is the potential for cane crop needs for N and P to be met by non-synthetic sources (e.g. soil, legumes, irrigation water, mill mud etc)?

27c. Evaluate the management options for reducing the need to apply fertiliser on cane farms (e.g. legumes, cane varieties)?

27e. What is the capacity to improve efficiency of fertiliser use through technological innovation?

27f. What are the lowest rates of mill mud that can be safely and practically applied to cane crops by mill district?

28b. What are the options for managing headlands, stream banks and drainage lines to minimise erosion of damaging sediment fractions?

Zonal mill mud – Herbert

1.6 This project and Reef Plan:

This project will assist in meeting the 2011–12 Reef Plan objectives. As a cross–correlation to the 2011–12 Reef Plan, following is the list of Reef Plan questions that this project will contribute to:

8. What are the water quality benefits associated with different land management practices in the cane industry?

17. What are the alternatives to existing commonly used residual weedicide used on cane and how effective are those alternatives and what is their environmental impact?

4. What is the effectiveness of water quality filters like floodplains, riparian areas and wetlands in reducing nutrients, sediments and pesticides?

It will also contribute to, but not necessarily directly address the following 2011–2012 Reef Plan Priority research questions:

9. What are the optimum/minimum rates of nutrient and pesticide applications for various crops? What type of pesticide gives the best efficacy and environmental outcome?

11. What are the barriers to improved management practice adoption and what practice change mechanism designs can overcome persistent barriers?

It will partially address the following priority question:

12. What are the new and emerging improved management practices and what are the water quality, productivity, economic and social values of these practices? Especially it will detail where such practices are well-documents as having both profitability and water quality benefits. [Note - it is not the intention of this project to focus on such practices. The emphasis will be more on practices that can be easily and cheaply adopted by the majority of growers to ensure at least compliance with the Regulations and preferably well exceed the outputs embedded in the objectives of the Regulations.]

1.7 This project and industry practices:

This project addresses the issues of producer choice and local circumstances. Substantial investment in R&D on improved practices in the sugar industry is underway and substantial effort is being made through Reef Rescue and Project Catalyst to foster improved practices.

Nevertheless adoption of smarter sugar growing practices above that prescribed by legislation remains the prerogative of growers. What this project will do is collate, document and present the diverse range of smarter practices in a form that will allow growers to select that suite of practices best suited to his/her local landscape and to his/her enterprise conditions and business model.

The project will be restricted to the three regulated Great Barrier Reef catchments – Wet Tropics and Herbert, Burdekin and Mackay Whitsunday. However, it will develop a framework that could be applicable for cane growing regions Australia-wide. The potential to roll out this approach across Queensland or Australia will be explored with alternative funding bodes, (e.g. SRDC/BSES), thereby providing a very important milestone in practice improvement for the entire eastern Australia sugar growing industry. This is particularly pertinent as both the Queensland and Australian Governments focus on increased agricultural productivity and profitability.

The project will deliberately not be directly reporting on the "ABCD" management practice framework, but will be organised in such a way as to allow any combination of management options to be assessed according to this framework. Generally speaking, the practices documented in this report are "B" or possibly "B+", being practices that are industry-leading but are also proven. This report uses the initial definition of "A" practices, being practices that are innovative, are likely to yield profitability and sustainability dividends, but are not yet proven.

The project will only provide information that is published or easily accessible through existing networks. It will not derive or recommend new suites of practices beyond those already proven to be in some way an improvement in profitability and sustainability. The project is also a point in time – as research findings, innovative practices are trialled and so on "B" practices will also change and presumably some of the practices currently "A" by being proven will become "B" practices. Much is underway in the innovation end of sugar cultivation. The practices in this Report therefore have a "use by" date and are likely to be superseded by even more profitable and sustainable practices within the next two to five years.

1.8 Extending the outputs of this project

Extension of the findings of this Report is beyond the remit of the project. Nevertheless extension is a high priority and came up as an issue that was substantially under-resourced in virtually all the discussions held during the conduct of the project. Suggestions are made in Chapter 5 as to how best to improve industry extension and how the outputs of this project could contribute.

1.9 This project and links to other initiatives

There are multiple initiatives underway on sugar industry practice from both sustainability and profitability perspectives. Some of these that have been closely involved in the conduct and outputs of this project include:

- Reef Plan Action 4 – previously DEEDI and now DAFF, being development and continual update of improved practices
- Paddock 2 Reef monitoring and analysis, setting up broad principles and agreed positions on the profitability and sustainability of various practices in the “ABCD” schema
- Reef Rescue funded R&D, incentive programs and synthesis information, with this project also contributing to the 2012 Reef Rescue forum
- NRM group activities and monitoring as part of ongoing work in Water Quality Improvement Plans
- Projects and activities commissioned by the then-DERM and Reef Protection Unit, now the Reef Water Quality Unit
- R&D commissioned through SRDC and BSES.

Chapter 2: Broad principles for cane farming practices

Management principles and strategies for sustainable and profitable sugarcane production can be broadly grouped within four categories:

Cropping systems – integrated practices that deliver profitability and sustainability across the environmental concerns of nutrient, weed and herbicide and soil and water management while simultaneously delivering to profitability agendas such as reduced labour costs, maximum production outputs, minimal cost inputs and flexibility so that risks such as variable weather can be accommodated through tactical on farm activities. Green cane trash blanketing is an example that meets all these criteria.

Soil and water management – practices that minimise negative risks to production and profitability such as water use efficiency while simultaneously providing maximum insurance against adverse environmental impacts off farm. Tailwater recycling is such a practice.

Nutrient management – practices that maximise plant uptake of nutrients towards highest possible productivity while minimising the likelihood of nutrient losses off farm. The highly regarded decision process of *6 Easy Steps* is an excellent example.

Weed management – practices that minimise the cost of inputs such as chemicals and labour, maximise production by reducing plant competition and minimising the likelihood of chemical losses off farm. Practices including cover crops, timing of application and use of knock down chemicals all meet this criterion.

Across all cropping industries there is always a suite of activities and concepts that underpin smart agricultural practices. These include:

- detailed property planning and knowledge
- record keeping and adaptive strategies and decision processes that build on the property plan and the results of record keeping
- matching practice to biophysical condition, such as varying fertiliser or irrigation rates and placement to match soil types
- tactical approaches that respond to variable and unpredictable stresses such as extreme weather events
- strategic approaches that respond to and take account of longer term stresses such as, changes in labour availability and commodity pricing
- innovative application of existing technology, often including testing and trialling new approaches.

The four chapters for the Wet Tropics, Herbert, Burdekin Dry Tropics and Mackay Whitsundays detail the smart practices that are well tried and tested and are being used by many growers in each of these regions. All these practices are both more profitable and more sustainable than the practices recommended under legislation. Tables within each regional chapter list these key practices in the same order as the four categories defined above.

Inherent in each regional list of smart practices are the following broad principles and strategies:

Soil and water management

Soil principles:

- *Minimise the risk of soil loss from the cropping area by minimising soil disturbance and by decreasing run-off quantity and velocity*
- *Undertake practices that will retain or enhance soil health – physical, chemical and biological*

Water principles:

- *Minimise any off farm run-off carrying fertiliser, herbicides and sediment, preferably capturing and recycling on-farm as part of maximising profitability*
- *Riparian resources should be protected or repaired to maintain ecological function and minimise riverbank erosion*
- *Maximise water use efficiency and mimic natural recharge and drainage on-farm, both rain and irrigation derived, to match plant and catchment water needs*

Key soil and water strategies:

- Develop and implement a soil and water management plan that maximises soil health [physical, chemical and biological] and matches water use to plant and catchment needs
- Monitor soil health and water use routinely to track improvements and identify any need to change practices
- Continually seek improvements in within-paddock crop management systems to deliver both soil and water principles
- Time within-paddock activities to match paddock biophysical conditions and variations caused by geographical location, weather events and seasonal variations
- Adopt the most efficient and cost effective irrigation and drainage systems practical, seeking to match water availability to varying plant needs and biophysical conditions
- Identify, monitor and manage hazard areas susceptible to accelerated erosion or degradation such as riparian lands, high slope areas, drains and channels and wetlands.

Nutrient management

Nutrient principle:

- *Soil test and apply fertiliser at a rate and in a manner that enhances cane production and profitability and minimises the risk of loss to the environment – essentially matching fertiliser application to plant requirements*

Strategies:

- Develop and implement a nutrient management plan and modify this plan in response to monitoring productivity and soil testing
- Gain an understanding of nutrient budgets, the nutrient needs of differing varieties, the role of legume cover crops, the variable uptake of nutrients over seasons, the potential losses such as leaching, denitrification and run-off
- Vary nutrient application rates and timing within crop cycles and responding to varying biophysical conditions

- Assess the risk of loss due to predicted weather conditions and irrigation prior to nutrient applications
- Apply nutrients accurately at the smallest scale practical - placement and calibration accuracy
- Apply fertiliser in precise locations and using methods and equipment that encourages optimal uptake by the crop and minimises the likelihood of losses

Weed management and chemicals

Principles:

- *Reduce overall weed pressure through Integrated Weed Management*
- *Apply herbicides in ways and timing that minimise the likelihood of movement beyond the target area*
- *Where practical, apply strategies that reduce the amount of PSII herbicides used, thereby reducing both cost and likelihood of losses off-farm*

Strategies:

- Develop, implement and adapt a weed management plan that decrease weed pressures
- Identify and record weed size, species, pressure, locations, and sources of spread and utilise control methods to match the weed control need
- Optimise control methods to the specifics of farm layout and crop cycle
- Utilise a mix of chemical and non-chemical control methods to minimise cost and maximise efficacy of control
- Put in place whole-of-farm hygiene methods to reduce the risk of spread of weeds
- Ensure herbicide application rates take account of weed type, growth stage and pressure giving preference to cheaper knockdown chemicals where possible
- Maximise flexibility in timing of application, considering such as weather predictions, the time in the weed cycle thereby reducing the seed bank and the crop cycle, plant, ratoon or cover crop
- Applying herbicides accurately and effectively at the smallest scale practical - placement and calibration accuracy

Chapter 3: Mackay Whitsunday [Central] region

3.1 Natural resource base – Mackay Whitsunday

Climate: Mackay Whitsunday has one of the most variable climate regimes of all of Australia. There are extremes of weather with great variation around the "average". There is a high "average" rainfall at 1,600mm but effective rainfall at about 800mm, with much variation around that. Excessive rain occurs particularly in January to March, but can be at almost any time with flooding/waterlogging common.

Conversely in Mackay Whitsunday, especially in *El Nino* years, it can be extremely dry from May up to end of December with significant need for irrigation, especially to ensure success in plant crops. Even in these dry years there can be significant heavy storms with runoff.

In *la Niña* years there can be excessive rain August to December, which is totally disruptive to farming operations, both harvest and planting.

Given the extreme variability between and within seasons, growers must take account for climate risk.

Soils and topography: Cane farming is the main intensive agricultural land use occupying about 19 per cent of the land area in Mackay Whitsunday region. The Mackay area can be divided into three broad landform patterns based on geological history:

- Floodplains and creek flats of the major streams and creeks (mainly south of the Pioneer River)
- Uplands on sedimentary rocks
- Uplands on volcanic and intrusive rocks.

Most sugarcane is grown on the flat to very gently sloping floodplains. The main soil on these floodplains is a duplex soil that has a sandy loam to clay loamy topsoil that overlies sodic clay subsoil. Cracking clay soils are also a significant soil group on the Pioneer River floodplain and these soils occur further away from the rivers and creeks in the back-plains and swamps which are dominated by the finer or clay particles. These heavy textured soils are generally poorly drained due to their high clay content.

The sedimentary rock formations of the rises and hills produce soils that are related to the rock type and degree of weathering. For example, acid, red, yellow and grey duplex and earthy gradational soils with sandy topsoils have formed on deeply weathered coarse grained sedimentary rocks which are predominantly sandstone. Similarly, red and yellow duplex soils with clay loamy surface soils occur on deeply weathered fine grained sedimentary rocks such siltstone, mudstone and shale. Generally all of these soils have bleached subsurface layers which show they have been extensively weathered and leached.

The uplands formed on volcanic rocks give rise to moderately deep to deep, strongly structured, red, brown and black gradational and non-cracking clay soils. These soils have clay loam to light clay surfaces overlying light to medium clay subsoils (gradational or uniform soils). The quartz-rich acid volcanic rocks however usually produce sandy or loamy surfaced sodic duplex soils. The smaller areas of intrusive rocks such as granite and granodiorite form mainly moderately deep, brown, non-sodic duplex soils with clay loamy surface soils and deep uniform sandy soils.

Landscape – Mackay Whitsundays – Pioneer Valley

3.2 Mackay Whitsunday sugar industry

Farm characteristics: The average farm size is about 100ha of sugar cane, which has increased from about 70ha over the last eight years with property aggregation. Many of the farming entities have a number of title deeds on which the cane is grown. This can hinder paddock layout and irrigation system decisions.

There is a trend toward bigger farms but the number of small title deeds which can and are being sold as lifestyle plots attract a higher price than just the economic value for sugar cane production. The distribution of farm sizes is skewed with about 30 per cent of growers producing 70 per cent of the cane. Each farm tends to have relatively small paddocks which generally goes with the terrain and drainage needs but does constrain some practices such as GPS controlled cropping systems.

Mackay Sugar is promoting leasing/share farming to increase overall enterprise size but this to date is not a significant method of increasing grower economies of scale. Landowners prefer to sell rather than lease thus purchasing land is the preferred method of expanding.

Approximately 40 per cent of ratoons are fertilised with contract applied dunder products. Mill mud is banded on the row at approximately 50t/ha. Irrigation water is limited with about 65 per cent of the area allocated between two and four megalitres per hectare. The majority of cane is harvested by contractors who are also growers.

Social attributes: Following is a summary from a social survey done in the Mackay Sugar region in 2011:

Age, farm size, enthusiasm and succession

- Change in age or farm size show no real difference in yield levels
- The growers were younger than expected with 73 per cent under 60 years of age
- Only 5 per cent of growers were over 70 years of age
- 11 per cent of growers have a low level of enthusiasm with another 30 per cent being moderately enthusiastic
- Yield trends downwards as enthusiasm declines
- The level of enthusiasm is evenly spread amongst all farm sizes and there is no particular age group which is more or less enthusiastic than any other
- About 50 per cent of growers plan for the family to take over the business and these tend to be the enthusiastic growers
- 25 per cent of growers are not sure who will take over the business and these tend to be the least enthusiastic
- 25 per cent of growers are planning to sell their farms when they retire

Labour issues

- About 50 per cent of growers work off farm and there is a yield trend downwards as the number of hours worked off farm increases
- 33 per cent of the area is managed by growers who do not have enough labour to get things done on time and there is a clear decline in the average yield of these growers
- This is about the same for being able to irrigate on time
- It tends to be the younger growers who work more off farm and don’t have enough labour to get things done on time

Share-farming or leasing

- 12 per cent of the area may consider leasing their farm to other growers and 48 per cent of growers may consider leasing more land
- Age, enthusiasm, working off farm and farm size don’t seem to be issues in determining growers who are prepared to lease their farms

Extension in the region has been readily available through BSES, Productivity Services (AgriServ Central) and Agri-business until recently. With the loss of BSES one to one extension, the Productivity Services have assumed this role. The BSES PEC unit effectiveness in providing information/knowledge to Productivity Service’s and consultants is yet to be proven.

Links to processing: One Mackay Sugar mill has closed in the last few years and this may have caused some milling capacity/length of milling season issues in the event of a “normal” season. Mackay Sugar has a PRS cane payment model where growers and millers share in improvements in cane quality and milling efficiency. Proserpine and Plane Creek still have the CCS payment system.

3.3 Key practices for the Mackay Whitsunday region

In summary the key suite of profitable and sustainable practices for the Mackay Whitsunday region and their role are as follows:

Practice	Cropping systems	Soil and water mgmt	Nutrient mgmt	Weed mgmt
1 – Fallow / break crop	✓	✓	✓	✓
2 – Record keeping system – Ag Dat	✓	✓	✓	✓
3 – Reduced tillage	✓	✓		✓
4 – Controlled traffic	✓	✓	✓	✓
5 – Irrigation strategies		✓		
6 – Drainage		✓		
7 – Accurate application			✓	
8 – Identifying locations for geo-referenced soil sampling			✓	
9 – Fertiliser timing, incorporation and weather effects			✓	
10 – Accurate application and timing of chemicals				✓
11 – Selecting control method for weed pressure / type				✓
12 – Focus on weed control in fallow and plant cane				✓

These are all detailed in the following section.

Issue – Cropping systems		
Practice 1 – Fallow/break-crop		
Description	Establish and manage a break-crop (preferably legume) in the fallow	
Agronomic benefits	Break the monoculture, improve soil health (soil organic matter, break pathogen cycles), allows use of alternative herbicide products, improves grass weed control, legume supplies nitrogen (slow release if not incorporated).	
Profitability	Cost of growing a green manure legume crop is close to the value of nitrogen input saved in plant cane. Potential positive gross margin from grain harvested. Difficult to generalise about dollar value from soil health	**Certainty** - proven
Water quality	Reduced opportunity for runoff & sediment loss compared to bare fallow. Reduced risk of N losses if not incorporated.	**Certainty** - proven
Requirements for implementation	Bean planter available, header available, cash flow for inputs. Understanding of break-crop agronomy and ensuring sufficient moisture for cane plant crop establishment	
Supporting information	▪ Fact sheets (DAFF), ▪ Garside AL, Bell MJ (2001). Fallow legumes in the Australian sugar industry: Review of recent research findings and implications for the sugar cane cropping system. Proceedings of the Australian Society of Sugar Cane Technologists,23:230-235 ▪ Garside AL, Bell MJ (2011). Growth and yield responses to amendments to the sugarcane monoculture: effects of crop, pasture and bare fallow breaks and soil fumigation on plant and ratoon crops. *Crop and Pasture Science* 62, 396 – 412. ▪ Pankhurst CE, Stirling GR, Magarey RC, Blair BL, Holt JA, Bell MJ, Garside AL (2005). Quantification of the effects of rotation breaks on soil biological properties and their impact on yield decline in sugarcane, Soil Biology and Biochemistry, Volume 37, pp. 1121-30 ▪ Garside AL, Watters TS, Berthelsen JE, Sing NJ, Robotham BG, Bell M J (2004). Comparisons between conventional and alternative sugarcane farming systems which incorporate permanent beds, minimum tillage, controlled traffic and legume fallows Proceedings of the Australian Society for Sugar Cane Technologists 26 (CD-ROM). ▪ Poggio M, Hanks M (2007). Fallow management - calculating the profitability of different fallow management options. The Sugar Research and Development Corporation, Queensland ▪ Van Grieken ME, Webster AJ, Coggan A, Thorburn P, Biggs J 2010. Agricultural management practices for water quality improvement in the Great Barrier Reef Catchments. CSIRO: Water for a Healthy Country National Research Flagship.	

Issue – Cropping systems		
Practice 2 – Record keeping system – AgDat		
Description	AgDat provides an integrated suite of applications to record farm related data into a spatial database. Farm inputs recorded may include nutrients, herbicides, pesticides, water as well as other farm management practices such as soil preparation activities, soil and leaf sample site locations, areas of planting and seed cane source as well as harvesting information. Growers are facing increasing external pressures to provide accurate and site related (spatial) data regarding farm inputs and farm management practices. AgDat uses the spatial extents of the paddocks as generated by the mill as the source of its base layer. Growers can record data via the AgDat web application or by the use of AgDat remote which automatically captures the farming activities as they occur using GPS and interpolation technologies. AgDat Pro is an application predominately used by advisers to provide a more sophisticated data recording platform. No matter what platform is used, all data is recorded into the one database.	
Agronomic benefits	GIS (Geographic Information Systems) have been developed to record, report and analyse spatial data. When recorded analysis can be performed between different spatial datasets based upon their geographic relationship to each other. The analysis of data can often highlight poor practices being used by a grower. Growers and their advisers may use this information to adopt better management practices with the obvious agronomic and economic benefits.	
Profitability	The improvements relating to profitability from the use of a spatial record keeping system is difficult to determine. However early detection & remedy of poor management practices can lead to effective and rapid improvements by the growing sector. Major benefits can be expected by having a system that records and stores all relevant data into the one database. All too often, most of this of type of data has been recorded and stored in a variety of locations using a multitude of different data storing platforms which makes retrieval and analysis a time consuming and expensive operation(sometimes not possible at all).	**Certainty** - mixture of proven and unproven ASSCT, Advisers, MSL, Agtrix
Water quality	On farm management practice data used in the Paddock 2 Reef monitoring program is reliant on data recorded and stored in AgDat. By having this data recorded, stored and retrieved from AgDat, improvements in farming operations that lead to a direct	**Certainty** - not proven Paddock 2 Reef monitoring, advisers,

	water quality improvement have been identified and used by the modelling programs.	
Requirements for implementation	Growers: Computer to access AgDat web, AgDat remote unit for automated data capture, analysis and reporting tools within AgDat (not yet fully developed). Advisers: AgDat Pro, Access to AgDat web and remote recordings, sophisticated analysis and recording tools (Not yet fully developed) Other users: access to aggregated reports and analysis(Not yet developed)	
Supporting information	▪ ASSCT papers, Paddock to Reef reports ▪ Van Grieken ME, Webster AJ, Coggan A, Thorburn P, Biggs J 2010. Agricultural management practices for water quality improvement in the Great Barrier Reef Catchments. CSIRO: Water for a Healthy Country National Research Flagship.	

Issue – Cropping systems		
Practice 3 – Reduced tillage		
Description	The practice of using a reduced number of tillage operations to prepare ground for planting. This can be as a result of a reduced number of "conventional" cultivations or as a result of targeted cultivation where only the row area is cultivated. This practice is referred to as zonal tillage.	
Agronomic benefits	Reducing the number of tillage operations results in improved soil structure as the soil peds are not broken down through excessive tillage. Improved soil structure leads to better water infiltration and drainage resulting in improved crop growth. Reduced tillage retains organic matter and improves soil biota.	
Profitability	By reducing the level of tillage the input costs of cane production are reduced through lower costs for fuel, labour, repairs/ maintenance and capital costs. Studies have shown a move to full zonal tillage can result in significant savings when compared to conventional practices.	**Certainty** - proven SYDJV, ASSCT Papers, P2R
Water quality	Reduced cultivation can lead to improved water quality as the soil is less prone to erosion. Better soil structure leads to improved infiltration resulting in less runoff.	**Certainty** - proven SYDJV, ASSCT Papers, P2R
Requirements for	Grower can implement reduced tillage by undertaking fewer tillage operations with their current tillage equipment.	

implementation	Adoption of zonal tillage will require the grower to purchase or modify equipment.
Supporting information	▪ East M (2010) Paddock to Reef Monitoring and Evaluation: Economic analysis of ABCD cane management practices for the Mackay Whitsunday region. Department of Employment, Economic Development and Innovation, Queensland

Issue – Cropping systems		
Practice 4 – Controlled traffic		
Description	Controlled traffic is the practice where all machinery wheel spacing's are matched to the row spacing. Where this practice is undertaken there is a defined area where traffic travels and defined area where the crop grows.	
Agronomic benefits	Controlled Traffic is one of the key principles of an improved farming system. The removal of random travel results in reduced compaction in the crop row which leads to improved soil condition. Improved yields should result from the implementation of the practice but these yield improvements have been difficult to assess to date	
Profitability	Studies have shown improvements in gross margins however the capital costs in conversion must be considered. Having a controlled traffic system enables the implementation of a zonal tillage system and/or reduces the number of operations resulting in reduced land preparation cost. Wider row spacing results in less travel per hectare for all field operations. Refer to Reduced Tillage information	**Certainty -** proven SYDJV, ASSCT Papers, BSES and Centre for Precision Agriculture
Water quality	Water quality benefit results from reduced runoff and sediment losses from the field due to improved soil structure and reduced compaction.	**Certainty** - proven SYDJV, ASSCT Papers, BSES and Centre for Precision Agriculture
Requirements for implementation	For a grower to implement controlled traffic they need to match all wheel and row spacing's. Most spacing's are matched to the cane harvester which is the least adjustable in width. This results in wider row spacing and necessitates the widening of all farm machinery used in crop. To fully control the traffic the use of a GPS is beneficial (grower or contractor owned).	
Supporting information	▪ Loeskow, N. and Cameron, T. and Callow, B. (2006) 'Grower Case Study on Economics of an Improved Farming System', *Proc. Aust. Sugar Cane Technol.,* Volume 28.	

	▪ Masters B, Rohde K, Gurner N, Higham W, Drewry, J (2008), Sediment, nutrient and herbicide runoff from cane farming practices in the Mackay Whitsunday region: a field-based rainfall simulation study of management practices, Queensland Department of Natural Resources and Water for the Mackay Whitsunday Natural Resource Management Group, Australia. ▪ Masters B, Rohde K, Gurner N, Reid D (2012) 'Reducing the risk of herbicide runoff in sugarcane farming through controlled traffic and early-banded application', Agriculture, Ecosystems and Environment. ▪ Garside AL, Bell MJ, Robotham BJ (2009).Row spacing and planting density effects on the growth and yield of sugarcane. 2. Strategies for the adoption of controlled traffic. Crop and Pasture Science, 60: 544 – 554. ▪ Garside A.L., Watters T.S., Berthelsen J.E., Sing N.J., Robotham B.G., Bell M.J. (2004), Comparisons between conventional and alternative sugarcane farming systems which incorporate permanent beds, minimum tillage, controlled traffic and legume fallows. Proceedings of the Australian Society for Sugar Cane Technologists 26 (CD-ROM). ▪ Garside AL (2005).The potential for permanent raised beds in sugarcane cropping systems.In Roth CH, Fischer RA and Meisner C.A. (EDS.) Evaluation and performance of permanent raised bed cropping systems in Asia, Australia and Mexico. Proceedings of ACIAR Workshop, Griffith, NSW, Australia, March 1 – 3, 2005. pp. 154 – 161. ▪ Garside A.L. (2006). Management of the interface between sugarcane cycles in a permanent bed, controlled traffic farming system. Proceedings of the Conference of the Australian Society of Sugar Cane Technologists. 118 ▪ Halpin N.V., Cameron T, Russo P.F. (2008). Economic Evaluation of Precision Controlled Traffic Farming in the Australian Sugar Industry: A Case Study of an Early Adopter. Proceedings of the Conference of the Australian Society of Sugar Cane Technologists. Volume 30. ▪ Tullberg J.N., Zeibarth L.J., Yuxia L (2001). Traffic and Tillage effects on run off, Australian Journal of Soil Research, Volume 39, pp. 249-57 ▪ Van Grieken M.E., Webster AJ, Coggan A, Thorburn P, Biggs J (2010). Agricultural Management Practices for Water Quality Improvement in the Great Barrier Reef Catchments. CSIRO: Water for a Healthy Country National Research Flagship.

Guidance – Mackay

Raised bed guidance - Mackay

Issue – Soil and water	
Practice 5 – Irrigation strategies	
Description	The Mackay Whitsunday region is constrained by the availability of water. Irrigation strategies are by far one of the most important tools in a farm management system to increase productivity, profitability and improve environmental outcomes. In light of this water is a limiting factor to maximising production but growers use water to maximise the efficacy of inputs and to use the balance to maximise productivity. Although practices are in place to incorporate nutrients and chemicals further strategies are required to maximise production from available water.
Agronomic benefits	Timeliness of farming operations is crucial. The availability of appropriate irrigation systems and quality as well as quantity of water are tantamount to maximising productivity and agronomic benefits. Apart from maintaining crop growth and soil cover, the timeliness of water applications after nutrient and chemical applications will increase the

	efficacy of those products as well as reduce the potential risk of movement of those products from the target area. In conjunction with BMP such as GCTB, break-crops and controlled traffic/minimum tillage irrigation strategies magnify the benefits of these practices thereby improving soil structure and fertility. It is well documented that on average there is an increase of 10t/ha of cane per 1ML of water applied. This will vary by soil type and application efficiencies.	
Profitability	Climate variability, soil type and effective rainfall will determine crop need. In Mackay this requirement could vary between 1-9 ML of irrigation depending on rainfall distribution. On average 5 ML to maximise crop growth. Irrigation system efficiency plays a significant role. Profitability is curtailed by inadequate supply of water because low cost high pressure systems are used due to the inability to repay expensive low pressure systems and forego higher efficiencies (economies of scale). Efficient systems double the gross margin/ha as opposed to inefficient systems if adequate supplies can be guaranteed. However there is still a need to put strategies in place to maximise use based on rainfall forecasting. Profitability of irrigation in most instances is a given but is a complex issue.	**Certainty** - proven CSIRO, BSES
Water quality	Early crop cover protects the soil. Appropriate application and scheduling of water "locks" in applied nutrients and chemicals in the soil or plants and greatly diminishes the risk of movement of these chemicals from farm.	**Certainty -** not well trialled but outcome suggests proven. Many growers use this strategy
Requirements for implementation	Supplementary irrigation strategies are required for the Mackay Whitsunday region. Require an integrated systems approach whereby industry and farm data can be used to populate WaterSense and economic models to provide to individuals the economic benefits of various water strategies under different systems, soil types and water allocations within the parameters of climate variability.	
Supporting information	▪ Attard S.J., Inman-Bamber N.G. (2011) Irrigation Scheduling in the Central Region: Making Every Drop Count, Proceedings of the Australian Society of Sugar Cane Technologists, Volume 33 ▪ Inman Bamber N.G. (2004) 'Sugarcane water stress criteria for irrigation and drying off, Field Crops Research, volume 89, pp. 107-22. ▪ WaterSense (CSIRO), BSES manuals, Canegrowers-Economic modelling	

Issue – Soil and water		
Practice 6 – Drainage		
Description	Cane fields are designed to allow surface water to runoff the field in a controlled manner. This design work considers the slope, the length of run and the erosion risk of the soil. Common structures used in the design work include: contour banks, grassed water ways, "v" drains and tail water dams. The aim of a good drainage design is to remove the water from the field over a 24 hour period in a controlled manner	
Agronomic benefits	Good drainage reduces the risk of water logging and therefore improved aeration, nitrogen use efficiency and root development. Water logging can result in cane yield reduction of up to 1 ton per day. Water logging of part of the field can result in the whole field becoming impassable and therefore limiting the timeliness of operations such as spraying herbicides, applying fertilisers, harvesting or planting.	
Profitability	Improved drainage can lead to improved yields through better growing condition and more timely field operations Reduced denitrification losses	**Certainty -** prove
Water quality	A good drainage system which sheds water over a 24hour period aids water quality. If drainage is too fast it increases the risk of erosion and sediment loss. Slow drainage can result in vegetation rotting in drains consuming oxygen leading to poor water quality entering waterways.	**Certainty -** not well trialled but outcome suggests proven in Paddock 2 Reef
Requirements for implementation	The design and construction of a good on farm drainage system often requires specialist designers working with specialist equipment. Much of the larger earth works is carried out by contractors, the smaller earth works are undertaken by the growers with their own equipment. One thing which is lacking is the drainage design service, which in the past was offered by the DPI.	
Supporting information	▪ Prosse I and Karssies L (2001), 'Designing filter strips to trap sediment and attached nutrient', *River and Riparian Land Management technical guideline,* Number 1, May 2001. Land and Water Australia, Canberra ▪ Allen D.E., Kingston G, Rennenberg H, Dalal R.C., Schmidt S (2010). Effect of nitrogen fertilizer management and	

	waterlogging on nitrous oxide emission from subtropical sugarcane soils. Agriculture, Ecosystems & Environment, 136, Pages 209-217 ▪ Hogarth D.M., Allsopp P (2000). Manual of cane growing. BSES, Indooroopilly, Australia. ▪ Hurney A, Schroeder B, Calcino D, Allsopp P (2008). SmartCane fallow and land management. BSES Limited Technical Publication TE08009.

Wavy disc cultivator – Mackay

Issue – Nutrient management	
Practice 7 – Accurate application	
Description	The accurate application of nutrients with a focus on applying the planned rate, in the right place and at the best possible time. Applying the planned rate is based on ensuring the equipment has been calibrated correctly and is

	possibly linked to some automated control unit to check accuracy of application. Applying in the right place is based on having equipment matched to row spacings so that fertiliser can be applied in the growing zone (not in the wheel tracks) where it is best placed sub-surface or incorporated soon after application.	
Agronomic benefits	Applying the crop needs based on a nutrient management plan i.e. Six Easy Steps– no over application which can lead to excessive vegetative growth, PRS reduction and sugar quality issues or under application which can reduce crop yields. Reduced crop yields can result in increased weed pressure from slower canopy closure or reduced trash blanket in ratoons. Applying fertiliser in the root zone for more efficient and effective use, not in wheel track, drains or on headlands. All nutrients applied will have a greater chance of being utilised by the crop.	
Profitability	No over-application which saves inputs costs and reduces the chances of lower PRS. No under-application that can reduce yield potential and have flow on affects from poor weed control etc. Improved crop yield from nutrient applications means an increased return per kg of nutrient applied.	**Certainty** - proven BSES (manuals, papers), ASSCT (papers) **In Progress** Project Catalyst DAFF Economic Model Farms
Water quality	Placement close to the growing crop means more rapid uptake of fertiliser. No over-application which means less available to be lost in run-off. No application in wheel tracks where run-off risk is greatest.	**Certainty -** proven Paddock 2 Reef Paddock Scale trials. **In Progress** Reef Rescue R&D, Reef Protection Plan R&D
Requirements for implementation	**Grower:** Nutrient Management Plan, Regular Equipment Calibration Process, Fertiliser Box (Stool Splitter, Side Dresser), Spreader, Automated Control Unit (optional) **Contract:** Liquid Applicator Fleet, Spreaders (Mill Mud, Ash) – these are tracked and linked to monitoring equipment	
Supporting information	▪ Schroeder B.L., Wood A.W., Moody P.W., Bell M.J., Garside A.L. (2005). Nitrogen fertiliser guidelines in perspective. Proceedings of the Australian Society of Sugar Cane Technologists., 27: 291-304 ▪ Salter B, Schroeder B.L., Wood A.W., Panitz J.H., Park G (2008). The use of replicated strip trials for demonstrating the effectiveness of different nutrient management strategies for sugarcane. Proceedings of the Australian Society of Sugar Cane Technologists.,.30: 361 ▪ Wood A.W., Schroeder B.L., Hurney A.P., Salter B, Panitz J.H. (2008). Research aimed at enhancing nitrogen management guidelines for the six easy steps program. Proceedings of the Australian Society of Sugar Cane Technologists., 30: 362 ▪ Wood A.W., Schroeder B.L., Dwyer R (2010). Opportunities for improving the efficiency of use of nitrogen fertiliser in the Australian sugar industry. Proceedings of the Australian Society of Sugar Cane Technologists., 32: 221-231 ▪ Schroeder B.L., Wood A.W., Sefton M, Hurney A.P., Skocaj D.M., Stainlay T, Moody P.W. (20105). District Yield	

	Potential: An appropriate basis for Nitrogen guidelines for sugarcane production. Proceedings of the Australian Society of Sugar Cane Technologists.,.32: 193 ▪ Schroeder B.L., Wood A.W., Moody, P.W., Panitz J.H., Agnew J.R., Sluggett R.J., Salter B (2006). Delivering nutrient management guidelines to growers in the central region of the Australian sugar industry. Proceedings of the Australian Society of Sugar Cane Technologists.,.28: 142-154 ▪ Chapman L.S. (1994), Fertiliser N management in Australia. Proceedings of the Australian Society of Sugar Cane Technologists.,.20: 84-92 ▪ Moody P.W., Panitz J.H. (2005). Sustainable Nutrient Management – Delivering the message to the Australian Sugar Industry. BSES, CSR, and the Department of Natural Resources and Mines; Queensland ▪ Schroeder B, Hurney A, Wood A, Moody P, Calcino D, Cameron T (2009a). Alternative nitrogen management strategies for sugarcane production in Australia: The essence of what they mean. Proc. Aust. Soc. Sugar Cane Technol. 31:93-103. ▪ Schroeder B, Panitz J, Linedale T, Whiteing C, Callow B, Samson P, Hurney A, Calcino D, Allsopp P (2009b). SmartCane harvesting and ratoon management. BSES Limited Technical Publication TE09004. ▪ BSES (manuals, papers), ASSCT (papers), SmartCane best management practice booklet series

Fertiliser box – for accurate N placement

Fertiliser box – rear view

Issue – Nutrient management	
Practice 8 – Identifying locations for geo-referenced soil sampling	
Description	Precision agriculture begins with the soil, which is the basic management unit in any paddock, and deals with the responses in crop growth to the many complex interactions including soil nutritional status and soil physical properties. The use of spatially generated data such as EC Maps, satellite imagery and harvester yield data have been adopted to help growers in selecting the best locations to sample and analyse soils to identify the significant differences in soil properties that often occur within sugar cane paddocks. These sampling points should be geo-referenced for future

	reference.	
Agronomic benefits	More efficient and cost-effective use of crop inputs (*e.g.* fertiliser, soil ameliorants, water, pesticides) will result from applying only the input level needed to support healthy crop growth on particular soil types. Using geo-referenced soil sample locations established from the analysis of key GIS layers (including soil EC responses) will provide growers with the best guide to understanding the underlying soil properties and hence a more accurate method of determining the required inputs for maximising sugar production within identified management areas. Geo-referencing allows repeat sampling in the same soil zone to more accurately monitor changes in soil properties and nutritional status over time.	
Profitability	Knowledge of relationships between soil properties and crop management strategies will provide pathways for continual on-farm improvements related to site specific activities such as: soil preparation strategies, application of plant nutrients, managing irrigation water and drainage. Improvements in these areas will lead to reduced inputs whilst maintaining or improving crop yields.	**Certainty** - proven SYDJV, ASSCT, BPS001, CSIRO, Centre for Precision Agriculture
Water quality	Site-specific applications of nutrients, pesticides and herbicides should be based on spatially defined management areas. Significant water quality improvements will be generated when inputs are targeted to compliment the relationship between soil properties and required crop needs.	**Certainty** - proven but further trials warranted ASSCT, BPS001, Mackay Whitsunday water quality Improvement plan, Mackay Whitsunday ABCD guidelines
Requirements for implementation	Key spatial datasets such as EC maps, yield variation maps, soil sampling equipment, GPS, spatial record keeping	
Supporting information	▪ Van Grieken ME, Webster AJ, Coggan A, Thorburn P, Biggs J (2010). Agricultural Management Practices for Water Quality Improvement in the Great Barrier Reef Catchments. CSIRO: Water for a Healthy Country National Research Flagship. ▪ Various SYDJV papers, Attachment 2 – SRDC project BPS001 – Final report, ASSCT papers (2009, 2012), Mackay Whitsunday Water Quality Improvement Plan	

Issue – Nutrient management		
Practice 9 – Timing, incorporation and weather effects		
Description	The application timing and placement of fertiliser effects crop uptake and potential losses. Sub-surface fertiliser application or surface applied and incorporated by overhead irrigation (without causing runoff) or cultivation (plant cane option) increases nutrient use efficiency. Timing application so that there is a crop to begin utilising the fertiliser. Use of rainfall forecasts to avoid fertiliser application when predicted run-off- causing events are imminent.	
Agronomic benefits	Getting fertiliser into the soil as quickly as possible enables more rapid crop uptake and reduces the potential for surface loss mechanisms such as nitrogen volatilisation (gaseous loss into the atmosphere) and movement in runoff.	
Profitability	Good practice can improve the efficiency of the applied nutrient, optimising yield and increasing income.	**Certainty** - proven BSES, ASSCT
Water quality	Subsurface application of fertiliser or incorporation soon after application eliminates one potential loss pathway. Application decisions based on rainfall forecasts and avoiding seasonal high rainfall periods also reduces chances of fertiliser loss. Timing application so that there is a crop to begin utilising the fertiliser leaves less of it exposed to other loss mechanisms.	**Certainty** - proven BSES, ASSCT
Requirements for implementation	Ground-engaging fertiliser applicators and/or ability to apply overhead irrigation. Access to real-time weather forecasts including rainfall amounts and probabilities.	
Supporting information	▪ BSES (manuals, papers) ASSCT (papers)	

Issue – Weed management	
Practice 10 – Accurate application and timing	
Description	The accurate application of chemicals with a focus on applying the planned rate, in the right place and at the best possible time. Applying the planned rate is based on ensuring the equipment has been calibrated correctly, correct nozzles and pressures are used and is possibly linked to some automated control unit to maintain accuracy of application. Applying in the right place is based on having the appropriate equipment matched to row spacing so that it can be applied in the correct zone for broadcast, directed, banded or inter-row operations. Applying at the best

	possible time is based on timing spray applications with respect to weed pressure, crop stage and the ability to incorporate through rainfall, irrigation or sometimes cultivation in plant cane. Avoid application when runoff causing rainfall is predicted.	
Agronomic benefits	Applying the correct rate to the target means no over-application which can damage the crop or under-application which results in poor weed control that can lead to yield losses and an increase in the weed seed bank in following years. Applying in the correct zone at the correct time for the most efficient and effective use of any spray applications. Timed to achieve the maximum weed kill from the chemical applied but also takes into account other weed controls such as cultivation in plant cane and a trash blanket in ratoons. Activated or incorporated so that can it can rapidly control the most amount of weeds in the window available.	
Profitability	No over-application which saves inputs costs and reduces the risk of any crop damage. No under-application that causes weed pressure to reduce yield. Replacement of expensive residual herbicides with cheaper knockdown chemicals where practical. Improved weed control due to getting the maximum benefit from any operation and an improved yield from reduced weed pressure.	**Certainty** - proven BSES (manuals, papers), ASSCT (papers) **In Progress** Project Catalyst DAFF Economic Model Farms
Water quality	No over-application which means less available to be lost in run-off Reduced residual application in wheel tracks where run-off risk is greatest. Reduced residual application at out of hand stage which is closer to the wet season where run-off risk is greatest. Incorporating applications reduces the risk of losses in run-off.	**Certainty** - proven Paddock 2 Reef Paddock Scale trials. **In Progress** Reef Rescue R&D, Reef Protection Plan R&D
Requirements for implementation	**Grower:** Weed Management Plan, Spray Equipment with correct nozzles/pressure/setup for Boom (broadcast), Droppers/Legs (Directed or Banded), Shields (inter-row), Regular Equipment Calibration Process. **Optional:** High Clearance Spray Rig, Shielded Sprayer, Multi-Tanks, Automated Control Unit	
Supporting information	▪ Silburn D.M., Foley J.L., and deVoil R.C. (2011). Managing runoff of herbicides under rainfall and furrow irrigation with wheel traffic and banded spraying. Agriculture, Ecosystems and Environment. (Article in press) ▪ Masters B, Rohde K, Gurner N, Reid D (2012) Reducing the risk of herbicide runoff in sugarcane farming through controlled traffic and early-banded application. Agriculture, Ecosystems and Environment (Article accepted) ▪ BSES (manuals, papers), ASSCT (papers), SmartCane best management practice booklet series, DAFF Boomspray Calibration Tool	

Issue – Weed management		
Practice 11 – Selecting control method for weed pressure/type		
Description	Banded pre-emergent application on the row with inter-row knockdown and vine control application as required (with shields if using glyphosate) on plant cane plus additional vine control late in the season if required. With adequate trash blanket (from 80tc) in ratoons vine control may be the only spray required late in the season. With a high level of weed infestation banded pre-emergent on the row with inter-row knockdowns as required. Knockdown used in fallow to reduce weed pressure and the need for chemical use in subsequent ratoons. All chemical choices based on site specific characteristics such as weed pressure, soil type, weed characteristics etc. and used according to label recommendations.	
Agronomic benefits	Weeds are controlled. No seed bank build up. Minimal soil disturbance.	
Profitability	Lower input costs with banding (reduced area sprayed) compared to 100 per cent coverage. Less expensive chemicals used inter-row and on fallow. Control methods maintains yield at reduced input costs. Chemicals selected give required weed control to maintain yield.	**Certainty** - proven. Note: there is the potential to have drift from inter-row applications and some yield loss. Risk of not being able to spray at right time for weed growth stage. Works if all goes well.
Water quality	Improved or reduced use of pre-emergent herbicide in high risk areas (Inter-row) reduces the risk of losses in runoff	**Certainty** - trials in progress but less load= less risk, so likely to be proven
Requirements for implementation	Weed management plan. Spray rig with banding capability. Shielded spray rig.	
Supporting information	▪ Fact sheets, demonstrations, comparisons between different shields/hoods (some do not work well). ▪ Van Grieken M.E., Webster A.J., Coggan A, Thorburn P, Biggs J (2010). Agricultural Management Practices for Water Quality Improvement in the Great Barrier Reef Catchments. CSIRO: Water for a Healthy Country National Research Flagship.	
Issue – Weed management		
Practice 12 – Focus on weed control in fallow and plant cane		
Description	High weed pressure in crop is generated and perpetuated by poorly controlled weeds in fallow. A clean fallow where weeds are not allowed to grow and set seed makes weed control less of a problem in subsequent crops. Plant cane	

	offers a follow-up opportunity to control weeds as bare soil enables wider choice of control options ranging from cultivation to a selection of residual herbicides.	
Agronomic benefits	In a "bare-fallow" situation non-selective herbicides offer good control of grass and broadleaf weeds. Specific problem species are more easily targeted and future populations reduced. In a legume cover crop selective grass and selective broadleaf herbicides can control most problems while giving the added benefit of soil health improvements and nitrogen contribution for subsequent cane.	
Profitability	Non-selective fallow herbicides like glyphosate are relatively cheap and can save having to use expensive, less reliable and potentially more crop-damaging in-crop herbicides. Failure to control in-crop weeds for as little as 4 weeks can reduce yield potential by 10 per cent.	**Certainty** - proven BSES, ASSCT
Water quality	More reliance on non-selective fallow herbicides (which are a "soft" option in terms of their impact on water quality) can lead to a reduction in weed pressure in-crop and reduce number of knockdown sprays and/or reduce the need for broadcast residual use. "Softer", less mobile chemicals used means less potential runoff of herbicides of concern. Substitution of herbicides for weed management in place of cultivation reduces the risk of sediment losses.	**Certainty** - proven Reef Catchments, ASSCT, BSES
Requirements for implementation	Properly maintained, correctly set-up and regularly calibrated boom-spray and in-crop spray equipment.	
Supporting information	▪ BSES (manuals, papers) ASSCT (papers)	

Chapter 4: Burdekin region

The lower Burdekin comprises approximately 86 000ha of irrigated agriculture with predominately sugar based production systems. There are two distinct regions within the lower Burdekin. The first is the coastal Delta which is characterised by soils with high infiltration properties and is predominantly irrigated with bore water pumped from the underground aquifer, although there is an increasing amount of irrigation water sourced from the Burdekin Dam. The second area is the Burdekin Haughton Water Supply Scheme, which is mainly irrigated with water sourced from the Burdekin Dam and is generally characterised by soils with inherent low permeability. Gypsum usage over 20 years has substantially increased the deep drainage characteristics of some of these soils. Numerous water supply and drainage channels intersect the region to transport water on and off farms. Some of this water is carried into the marine environment with potential to contain nutrients and pesticides lost from farming enterprises.

The region has experienced significant challenges and structural changes in recent years including:

- above average and prolonged wet seasons and out of season rainfall events
- extended harvest seasons due to weather and mill performance
- introduction of Reef Protection legislation
- restructuring of BSES Limited (extension staff being made redundant)
- critical lack of dedicated extension /farming systems personnel.

4.1 Natural resource base – Burdekin

Climate: The Burdekin region is situated in the dry tropics with a wet season that generally occurs between mid-January and late March. About 70 per cent of the annual rainfall is received during this time. The long term average annual rainfall is about 1000mm. The extended dry season makes irrigation imperative for most crop production activities.

Soils and topography: The Burdekin has a relatively flat topography making it ideal for furrow irrigation. The coastal Delta area is characterised by light textured, freely draining soils, predominantly irrigated from underground bores and supplemented by surface water sourced from the Burdekin Dam. The Burdekin Haughton Water Supply Scheme is characterised by heavy textured soils that are more prone to water-logging events.

Irrigation: The main source of water is from the Burdekin Falls Dam. Sugarcane farming in the Burdekin is a fully irrigated system, with irrigation water being the primary conduit of movement of nutrient and pesticides from the sugarcane root zone via surface runoff to drains and watercourses, and through deep drainage losses into the aquifer. Furrow irrigation is the dominant irrigation practice with less than two per cent of farms using drip or overhead low pressure systems.

Groundwater levels in the Burdekin Haughton Water Supply Scheme have risen markedly over the past 20 years, due to the hydrological changes from tree clearing and the addition of irrigation water. These effects have been exacerbated by the addition of soil ameliorants such as gypsum and leakage from supply channels and drainage infrastructure.

Nutrient and pesticide losses from Burdekin Haughton Water Supply Scheme farms are largely influenced by dry season irrigation runoff into SunWater drains and natural watercourses. This is in contrast to most other sugar regions where wet season events are the usual mode of pollutant movement. (Davis et al, 2011).

Little discharge from the Burdekin sugarcane growing region flows into the Burdekin River, aside from groundwater inputs. Most discharge on the northern side of the River flows through the Barratta Creek system and the Haughton River, before entering Bowling Green Bay. On the southern side of the River, discharge flows into Upstart Bay through minor creeks (Crawford 2008).

4.2 Burdekin sugar industry

Farm characteristics: The Burdekin sugarcane growing sector has 630 farming entities, although 30 farming groups supply nearly three million tonnes (out of a total of 8 to 8.5 million tonnes). Delta farms are generally smaller with non-uniform block shapes; Burdekin Haughton Water Supply Scheme farms are generally larger with more uniform block sizes.

Social attributes:

- There is a severe shortage of extension and agronomic support for growers.
- Continuous crushing since 1994 has altered the dynamics of the social fabric of the community affecting sporting, cultural, recreational and social activities within the district.
- Irrigation demands mean a nearly continuous workload for Burdekin cane growers.
- The harvesting sector is dependent on skilled workers but only on a seasonal basis, making staff retention difficult.
- There is major competition for labour with the mining resources sector, and this particularly affects the harvesting sector.

Green Cane Harvesting: Green cane trash blanketing (GCTB) is a viable option in most cane growing regions of Queensland; however this practice does have difficulties in the Burdekin. Retaining the harvested green material in the furrows causes retardation of water movement. Under a furrow irrigated GCTB system, waterlogging can be a significant problem on the heavy clay soils, whilst on the light textured soils deep drainage losses can be severe, leading to poor irrigation efficiencies. Harvesting Burdekin crops green can be slow, expensive and difficult due to their size.

Links to processing: The Burdekin has four sugar mills, all owned by Wilmar. The harvesting and milling sector are currently unable to handle the total Burdekin crop as green cane. Moving to green cane harvesting would mean an extended harvesting period and require an increase in bin infrastructure, as well as changes in the mill to deal with the additional extraneous matter.

- In contrast to other sugarcane growing regions, trucks form the backbone of the harvesting sector in the Burdekin, although in-field transporters are becoming more common.

- Changes to the mills are needed to be able to process green cane.

4.3 Key practices for the Burdekin region

In summary, the key suite of profitable and sustainable practices for the Burdekin and their role are as follows:

Practice	Cropping systems	Soil and water mgmt	Nutrient mgmt	Weed mgmt
1 – Pre-formed beds.	✓	✓	✓	
2 – Legume fallow crops	✓	✓	✓	✓
3 – Double disc opener planter	✓	✓		
4 – GPS guidance	✓	✓	✓	✓
5 – Irrigation tail water recycling pits		✓		
6 – Optimising furrow irrigation		✓		
7 – Land forming		✓		
8 – Nutrient rate optimised			✓	
9 – Appropriate use of herbicide technologies				✓
10 – Optimised fallow weed control				✓

These are all detailed in the following section.

These practices need to be looked at in total – preferably being undertaken with appropriate management of all facets of the crop production system, with timeliness of operations being of paramount importance. Individual farm characteristics will determine the ease of implementation of these practices and these will include:

- Farm size
- Cash flow
- Farm/block layout
- Available machinery
- Infrastructure
- Availability of contractors
- Grower experience/attitude

<table>
<tr><td colspan="3">Issue: Cropping systems</td></tr>
<tr><td colspan="3">Practice 1 – Pre formed beds</td></tr>
<tr><td>Description</td><td colspan="2">Cultivation operations and forming of raised beds to be undertaken before the wet season.</td></tr>
<tr><td>Agronomic benefits</td><td colspan="2">▪ Enables minimum tillage planting
▪ Consolidation of beds over the wet season, allows for enhanced soil water infiltration and water holding capacity
▪ Allows for improved trafficability for early planting operations, which is more relevant for BHWSS soils.</td></tr>
<tr><td>Profitability</td><td>▪ Limited tillage operations post planting
▪ Greater yield potential due to earlier planting (pre winter)
▪ Planting on moisture reduces initial irrigation inputs</td><td>Certainty - medium-high
Well established in BHWSS since 2006, earlier planting windows have a high degree of certainty</td></tr>
<tr><td>Water quality</td><td>▪ Potential for reduced deep drainage losses
▪ Less sediment loss through reduced tillage
▪ Greater yield potential should lead to optimum use of nutrients</td><td>Certainty - low – medium; not yet proven</td></tr>
<tr><td>Requirements for implementation</td><td colspan="2">▪ Bedformer is required, although contractors are available
▪ For growers with greyback cane grub issues moving to raised pre-formed beds means they have to shift from granular (SuScon maxi) to liquid (Confidor) products for cane grub control.
▪ GPS is strongly recommended for land preparation operations pre bed forming

Note: post wet season bed forming is not recommended for most soils (except heavy clay soils) as the disruption to soil structure from the cultivation operations can cause major difficulties with water infiltration into the fresh beds. Generally this practice has less obvious benefits on delta soils since they have better trafficability under wet conditions. However, the soil physical and biological benefits of preformed beds are substantial, regardless of soil type.</td></tr>
<tr><td>Supporting information</td><td colspan="2">▪ Attard S.J., Thornburn P.J., Biggs J, Kemet J, Anderson T (2008). Farming practices to meet the water quality challenge in the Burdekin region. Proc. Aust. Soc. Sugar Cane Technol., 30:353-354
▪ Garside A.L. (2006) Management of the interface between sugarcane cycles in a permanent bed, controlled traffic farming system. Proceedings of the Conference of the Australian Society of Sugar Cane Technologists. 118
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</table>

	Mexico. *Proceedings of ACIAR Workshop, Griffith, NSW, Australia, March 1 – 3, 2005. pp. 154 – 161.* ▪ Garside, A.L., Watters, T.S., Berthelsen, J.E., Sing, N.J., Robotham B.G., Bell, M.J. (2004), Comparisons between conventional and alternative sugarcane farming systems which incorporate permanent beds, minimum tillage, controlled traffic and legume fallows Proceedings of the Australian Society for Sugar Cane Technologists 26 (CD-ROM).

Zonal rotary hoe tilling three rows in one pass

Issue: Cropping system		
Practice 2 – Legume fallow crop		
Description	Plant legumes onto pre formed beds in Dec-early Jan	
Agronomic benefits	▪ Improved soil health through better soil biology, chemical and physical characteristics ▪ Reduced granular nitrogen inputs, ▪ Reduced chemicals applied in subsequent cane crop if weeds controlled early. ▪ Better soil retention in wet season events when compared to bare fallow ▪ Planting legumes on beds provides the opportunity to plant cane with DDOP planters earlier than would be possible with conventionally planted cane, since the legume crop will reduce soil moisture levels and allow earlier trafficability.	
Profitability	▪ Increased fallow operations and inputs (seed, irrigation, herbicides etc), ▪ reduced cane crop inputs (herbicide, nitrogen) and improved yield potential should improve overall profitability ▪ Opportunity to harvest grain for profit	**Certainty - m**edium – depends on seasonal conditions, seed quality and grower experience. Trials required to prove benefits
Water quality	▪ Unknown- this needs to be determined. There may be additional N spike in runoff/ deep drainage water as the legume material decomposes. ▪ Management options such as raking of the legume residue on top of the beds prior to cane planting and irrigation is being trialled by one or two growers to minimise the potential loss pathways (although no monitoring is occurring)	**Certainty -** low – may be a surplus of nitrogen to crop requirements during cane establishment phase. Possible denitrification of legume N during first irrigation events or heavy rainfall. Trials required
Requirements for implementation	▪ Legume planter – contractors available BUT timing of planting operations is critical, agronomic support for pest control ▪ Mulcher or harvester required – contractors available ▪ Planting legumes on the 'flat' is more difficult to establish and the crop must be incorporated before cane planting. When the crop is incorporated, there is the potential for a large release of organic N. This N can be lost via denitrification or volatilisation from the cropping system.	
	▪ Garside A.L., Bell M.J. (2001). Fallow legumes in the Australian sugar industry: Review of recent research findings and implications for the sugar cane cropping system. Proceedings of the Australian Society of Sugar Cane Technologists, 23:230-235 ▪ Garside A.L. Bell M.J. (2011). Growth and yield responses to amendments to the sugarcane monoculture: effects of crop, pasture and bare fallow breaks and soil fumigation on plant and ratoon crops. *Crop and Pasture Science* 62, 396 –	

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Issue: Cropping system		
Practice 3 – Double disc opener planting (DDOP)		
Description	Using a minimum tillage planting system into pre formed beds minimises soil disturbance and subsequent tillage operations	
Agronomic benefits	Improved soil structure through: ▪ less tillage ▪ less machinery operations, ▪ Less weed pressure ▪ Reduced initial water inputs(where planted on moisture)	
Profitability	▪ Greater yield potential through earlier planting ▪ Less tractor operations ▪ Less time/tillage	**Certainty** Medium – High Very widely adopted in the BHWSS since 2005 However, DDOPs are not widely used on delta soils, mainly due to the difficulty in planting

		cane deep enough to minimise stool tipping. It is also easier to apply SuScon Maxi for grey back cane grub control in a conventional planting system than under a minimal tillage DDOP system.
Water quality	▪ Improved soil structure should lead to greater yield potential	**Certainty** Medium – no specific research data
Requirements for implementation	▪ Many contractors have DDOP capability ▪ For some sandy textured delta soils DDOP is unsatisfactory because of poor water infiltration into beds. It is also difficult to place the setts deep enough into the hill to avoid stool tipping.	
Supporting information	▪ Garside A.L. (2005).The potential for permanent raised beds in sugarcane cropping systems. In Roth C.H., Fischer R.A. and Meisner C.A. (EDS.) Evaluation and performance of permanent raised bed cropping systems in Asia, Australia and Mexico. Proceedings of *ACIAR Workshop*, Griffith, NSW, Australia, March 1 – 3, 2005. pp. 154 – 161. ▪ Garside A.L. (2006). Management of the interface between sugarcane cycles in a permanent bed, controlled traffic farming system. Proceedings of the Conference of the Australian Society of Sugar Cane Technologists. 118 ▪ Garside A.L., Bell M.J., Robotham B.J. (2009).Row spacing and planting density effects on the growth and yield of sugarcane. 2. Strategies for the adoption of controlled traffic. Crop and Pasture Science, 60: 544 – 554. ▪ Halpin N.V., Cameron T, Russo P.F. (2008). Economic Evaluation of Precision Controlled Traffic Farming in the Australian Sugar Industry: A Case Study of an Early Adopter. Proceedings of the Conference of the Australian Society of Sugar Cane Technologists. Volume 30. ▪ Tullberg J.N., Zeibarth L.J., Yuxia L (2001). Traffic and Tillage effects on run off, Australian Journal of Soil Research*,* Volume 39, pp. 249-57. ▪ Stephanie AS, Jenkins A, Lines-Kelly R (2009). Saving Soil ~ A landholder's guide to preventing and repairing soil erosion, Technical publication by NSW DPI and Northern Rivers Catchment Management Authority Implementing an efficient and improved farming system (www.reefcatchments.com.au) ▪ Van Grieken M.E., Webster A.J., Coggan A, Thorburn P, Biggs J (2010). Agricultural Management Practices for Water Quality Improvement in the Great Barrier Reef Catchments. CSIRO: Water for a Healthy Country National Research Flagship.	

Issue : **Cropping systems**

Practice 4: GPS guidance (auto-steer)

Description	Tractor fitted with capacity to steer to within 20mm accuracy using GPS technology.	
Agronomic benefits	▪ GPS is an essential pre-requisite for precision farming and controlled traffic farming systems. ▪ GPS also allows for operations to begin at any part of the field; this is crucial for precision farming systems. ▪ GPS technology also allows linkage of GPS controllers to flow rate controllers (fertiliser and herbicide) to allow precision variable rate application, as well as automated recording and mapping of product applications. ▪ The ability to have the cropped area in an exact location has many benefits. Driving in straight lines with equidistant rows means a much more efficient mechanical harvesting system (as adjacent rows are not knocked down by the harvester as they are with odd or narrow rows).	
Profitability	▪ Should be more profitable in the long term, but difficult to ascertain.	**Certainty -** low- medium; not well proven
Water quality	▪ GPS enables a range of precision farming operations to be undertaken e.g. prescription farming, yield mapping, variable rate applications etc. ▪ These practices should lead to improved farming attitudes and better water quality.	**Certainty –** low; not proven
Requirements for implementation	▪ Need hardware(~ $33 000) if starting out ▪ Need the expertise to assess reasons for yield variation from yield maps and for formulating appropriate prescriptions for variable rate applications. ▪ Must have GPS guidance on all machinery (including harvesters and haulouts) to have full benefits of controlled traffic systems	
Supporting information	▪ Halpin N.V., Cameron T, Russo P.F. (2008) Economic Evaluation of Precision Controlled Traffic Farming in the Australian Sugar Industry: A Case Study of an Early Adopter. Proceedings of the Conference of the Australian Society of Sugar Cane Technologists. Volume 30. ▪ Loeskow N, Cameron T, Callow B (2006) Grower Case Study on Economics of an Improved Farming System, Proceedings of the Conference of the Australian Society of Sugar Cane Technologists, Volume 28. ▪ Poggio, M and Page J (2010), *Economic case study of ABCD cane management practices in the Burdekin River Irrigation Area (BRIA) region.* Department of Employment, Economic Development and Innovation, Queensland. http://era.deedi.qld.gov.au/3123/	

	▪ Poggio M and Page J (2010) Economic case study of ABCD cane management practices in the Burdekin Delta region. Department of Employment, Economic Development and Innovation, Queensland. http://era.deedi.qld.gov.au/3124/ ▪ Poggio M.J. and Page J and Van Grieken M.E. (2010), Paddock to Reef Monitoring & Evaluation - Economic analysis of 'ABCD' cane management for the Burdekin River Irrigation Area. Department of Employment, Economic Development and Innovation, Queensland. ▪ Poggio M.J. and Page, J and Van Grieken M.E. (2010), Paddock to Reef Monitoring & Evaluation - Economic analysis of 'ABCD' cane management for Tully. Department of Employment, Economic Development and Innovation, Queensland. ▪ Van Grieken M.E., Webster A.J., Coggan A, Thorburn P, Biggs J (2010). Agricultural Management Practices for Water Quality Improvement in the Great Barrier Reef Catchments. CSIRO: Water for a Healthy Country National Research Flagship.

Recycle pit - Burdekin

Issue: Soil and water management		
Practice 5 – Irrigation tail water recycle pits		
Description	**Capture of farm runoff water and subsequent re-use**	
Agronomic benefits	▪ Lessens reliance on Sunwater supply system for irrigation start up, particularly in peak demand periods, ▪ Provides extra versatility in irrigation management. ▪ Captures fertiliser and chemical leaving paddock and returns these inputs to the farm. ▪ Applies to BHWSS farms rather than delta farms, since on delta farms there is very little surface water runoff.	
Profitability	▪ Variable – depends on price of water, amount captured, on farm infrastructure and pumping costs ▪ Cost of pit construction and pump and pipelines can be significant (in the order of $50 000 - $300 000)	**Certainty-** variable, low – very high
Water quality	▪ Capture of farm runoff and reuse means less nutrients and herbicides leaving farms, entering drains and reaching waterways	**Certainty** - very high; proven
Requirements for implementation	▪ Farm infrastructure to construct pit , install pipelines and pumping systems ▪ Not all soil types are suitable for recycle pits (i.e. freely draining soils) and so this practice is not common practice in the Burdekin delta.	

Issue: Soil and water management		
Practice 6 – Optimising furrow irrigation		
Description	Optimisation of Inflow rates, time to cut-off , appropriate scheduling and volume applied	
Agronomic benefits	▪ Increased crop production and less losses (particularly nitrogen) due to matched irrigation requirement	
Profitability	▪ Profitability should be enhanced by optimising irrigation inputs – although some growers are limited by farm irrigation supply infrastructure	**Certainty –** high; proven
Water quality	• Matched irrigation applications to crop requirement will lead to	**Certainty –** high; proven

	less losses to environment	
Requirements for implementation	Education/Extension of the following principles; ▪ Inflow rates optimised to minimise deep drainage ▪ Cut-off time optimised to minimise surface runoff and deep drainage ▪ Irrigation scheduled to maximise crop performance and minimise environmental losses Crop water use requirements –i.e.: RAW – readily available water in soil ▪ Carry out SIRMOD simulation(or equivalent) to understand paddock water dynamics, and model improvements in inflow rates and time to cut-off ▪ Use of irrigation scheduling tools: minipans, tensiometers, capacitance probes ▪ End of furrow monitors (with or without telemetry) These principles are extremely important in the context of improving water quality, and are often challenging to implement at an individual farm level (due to many factors including supply, infrastructure, weather, harvest and labour constraints). A well structured education and extension program relating to optimisation of irrigation is essential.	
Supporting information	▪ Inman-Bamber N.G., Webb W.A., Verrall S.A. (2005) Participatory irrigation research and scheduling in the ORD:R&D. Proceedings of the Australian Society of Sugar Cane Technologists.,27: 155 ▪ Qureshi M.E., Wegner M.K., Harrison S.R., Bristow K.L. (2001). Economic evaluation of alternative irrigation systems for sugarcane in the Burdekin delta in north Queensland, Australia, in Water Resource Management, edited by Brebbia CA, Anagnostppoulos K, Katsifarakis K, Cheng A.H.D. WIT Press, Boston, 47-57 ▪ Poggio M.J., Hesp C, Attard S,J,, Cameron T (2010) A case study on the economics of overhead irrigation in the lower Burdekin, Proceedings of the Australian Society of Sugar Cane Technologists. Volume 32.	

Issue: **Soil and water management**		
Practice 7 – Land forming		
Description	Levelling of blocks to optimise irrigation, improve drainage and boost subsequent crop performance	
Agronomic benefits	▪ Reduced water logging, particularly in the BHWSS area ▪ Increased irrigation efficiency ▪ More uniform plant stand	
Profitability	▪ enhanced crop performance	**Certainty –** high; proven
Water quality	▪ Reduced deep drainage	**Certainty –** medium; likely to benefit

	▪ Reduced potential for denitrification and volatilisation of nitrogen based fertilisers	
Requirements for implementation	Contractor is usually required. It is critical that land forming be conducted pre-wet season to minimise soil compaction effects. Land forming can be undertaken using Laser or GPS operating (Optisurface or MultiPlane) systems	
Supporting information	▪ Allen D.E., Kingston G, Rennenberg H, Dalal R.C., Schmidt S (2010). Effect of nitrogen fertilizer management and waterlogging on nitrous oxide emission from subtropical sugarcane soils. Agriculture, Ecosystems & Environment, 136, Pages 209-217 (Paper looks into denitrification losses and suggests management options for reducing losses from denitrification). ▪ Thorburn P, Davis A, Attard S, Milla R, Anderson T, McShane T (2007). Best Management Practices to Improve the Quality of Water Leaving Irrigated Sugarcane Farms: Guidelines for the Burdekin Region; ACTFR Report No. 07/36. ▪ Bryant K, Philip S, Hughes K, Willis R (2012) Mapping of environmental characteristics important for Reef water quality Burdekin and Mackay Whitsunday priority catchment: Assessment methodology, Land Resource Assessment, Department of Science, Information Technology, Innovation and the Arts, Brisbane. [Report provides information and maps of the natural landscape features (or environmental characteristics) that influence the movement of contaminants off-property via surface water transport processes	

Issue – Nutrient management		
Practice 8 –Nutrient rate optimised		
Description	Nutrient rate matched to crop requirements based on a soil test from a soil management zone	
Agronomic benefits	▪ Crop yield potential maximised	
Profitability	▪ Inputs matched to crop requirements lead to greatest profitability	**Certainty** - low-medium
Water quality	▪ Inputs matched to crop requirements lead to least potential for losses	**Certainty** - medium-high; proven
Requirements for	▪ Currently there is extremely limited local data available to confirm that 6ES nitrogen rates are the optimum rate. A series of N rate trials are currently underway and as results become available, further refinement of actual rates will occur.	

implementation	These trials need to occur over a full crop cycle and a range of seasonal conditions. ▪ Poor irrigation management may negate the benefits of optimised nutrient management ▪ Other cropping system issues such as poor weed control, variety selection and excessive cultivation as well as large rainfall events can also lead to fertiliser losses which may lead to reduced crop yield potential. ▪ A better understanding of yield limiting factors within blocks to allow growers to make informed decisions on their nutrient management plans.
Supporting information	▪ Calcino D, Schroeder B, Hurney A, Allsopp P (2008). SmartCane plant cane establishment and management**.** BSES Limited Technical Publication TE08010. ▪ Schroeder B, Hurney A, Wood A, Moody P, Calcino D, Cameron T (2009a). Alternative nitrogen management strategies for sugarcane production in Australia: The essence of what they mean. Proc. Aust. Soc. Sugar Cane Technol. 31:93-103. ▪ Schroeder B, Panitz J, Linedale T, Whiteing C, Callow B, Samson P, Hurney A, Calcino D, Allsopp P (2009b). **SmartCane harvesting and ratoon management.** BSES Limited Technical Publication TE09004. ▪ Chapman LS (1994), Fertiliser N management in Australia .Proceedings of the Australian Society of Sugar Cane Technologists.,20: 84-92 ▪ Thorburn P.J., Biggs J.S., Attard S.J., Kemei J (2011). Environmental impacts of irrigated sugarcane production: Nitrogen lost through runoff and leaching. Agriculture, Ecosystems & Environment, Volume 144, Number 1, pp. 1-12 ▪ Schroeder B.L., Wood A.W., Moody P.W., Bell M.J., Garside A.L. (2005). Nitrogen fertiliser guidelines in perspective. Proceedings of the Australian Society of Sugar Cane Technologists.,27: 291-304 ▪ Van Grieken M.E., Webster A.J., Coggan A, Thorburn P, Biggs J (2010). Agricultural Management Practices for Water Quality Improvement in the Great Barrier Reef Catchments. CSIRO: Water for a Healthy Country National Research Flagship. ▪ Salter B, Schroeder B.L., Wood A.W., Panitz J.H., Park G (2008). The use of replicated strip trials for demonstrating the effectiveness of different nutrient management strategies for sugarcane. Proceedings of the Australian Society of Sugar Cane Technologists.,30: 361 ▪ Wood A.W., Schroeder B.L., Hurney A.P., Salter B, Panitz J.H. (2008). Research aimed at enhancing nitrogen management guidelines for the six easy steps program. Proceedings of the Australian Society of Sugar Cane Technologists., 30: 362 ▪ Wood A.W., Schroeder B.L., Dwyer R (2010). Opportunities for improving the efficiency of use of nitrogen fertiliser in the Australian sugar industry. Proceedings of the Australian Society of Sugar Cane Technologists., 32: 221-231 ▪ Schroeder B.L., Wood A.W., Sefton M, Hurney A.P., Skocaj D.M., Stainlay T, Moody PW (2010). District Yield Potential: An appropriate basis for Nitrogen guidelines for sugarcane production. Proceedings of the Australian Society of Sugar Cane Technologists.,32: 193 ▪ Schroeder B.L., Wood A.W., Moody, P.W., Panitz J.H., Agnew J.R., Sluggett R.J., Salter B (2006). Delivering nutrient management guidelines to growers in the central region of the Australian sugar industry. Proceedings of the Australian

	Society of Sugar Cane Technologists., 28: 142-154 ▪ Moody P.W., Panitz J.H. (2005). Sustainable Nutrient Management – Delivering the message to the Australian Sugar Industry. BSES, CSR, and the Department of Natural Resources and Mines; Queensland ▪ Sugarcane farmer of the year reducing run-off, Reef Water Quality Plan, Measuring Success; http://www.reefplan.qld.gov.au/measuring-success/case-studies.aspx#sugarcane ▪ Chapman L.S. (1994), Fertiliser N management in Australia. Proceedings of the Australian Society of Sugar Cane Technologists.,20: 84-92 ▪ Hunt, J (2011) Saving money by applying mill mud with precision. Soil Health. Australian Cane Grower: April 2011:16-18 ▪ Barry G.A., Rayment G.E., Bloesch P.M., Price A, Qureshi M.E. (2002). ▪ Management of sugar industry by-products and municipal biosolids on canelands. In 'Managing soils, nutrients and environment for sustainable sugar production'. (Ed.) Bruce, R.C. CRC for Sustainable Sugar Production. Townsville. Pp. 129 – 136. ▪ Bloesch P.M., Barry G.A. Rayment G.E., Beattie R.N. (2003). Stockpiled mill mud/ash: environmental implications and changes in nutrient value with age. Proceedings of the Australian Society of Sugar Cane Technologists *25*

Issue – Weed management		
Practice 9 – Appropriate use of herbicide technologies		
Description	Use of improved technologies such as: nozzles suitable for job, flow rate controllers, shielded sprayers, Envirodrums (100 or 110L re-useable drums designed for nil operator contact with chemicals)	
Agronomic benefits	▪ Herbicides applied more effectively to target ▪ Enhanced control of application rate and subsequent improved weed control	
Profitability	▪ Increased cost to purchase technology which should be compensated by improved weed control	**Certainty -** medium - high
Water quality	▪ More targeted and improved weed control should lead to less offsite losses ▪ Over time reduced weed pressure will lead to less chemical usage ▪ Envirodrum benefits include reduced number of chemical	**Certainty -** low - medium

	containers, less operator exposure to chemicals, reduced potential for spillage and no need for rinsing of containers. ▪ Shielded sprayers allows use of glyphosate based herbicides for use in crop situations	
Requirements for implementation	▪ Nozzles, flow rate controllers, Envirodrums, shielded sprayers ▪ The success of these technologies is dependent on timeliness of operations.	
Supporting information	▪ Silburn D.M., Foley J.L., and deVoil R.C. (2011). Managing runoff of herbicides under rainfall and furrow irrigation with wheel traffic and banded spraying. Agriculture, Ecosystems and Environment. (Article in press). ▪ Masters B, Rohde K, Gurner N, Reid D (2012) Reducing the risk of herbicide runoff in sugarcane farming through controlled traffic and early-banded application. Agriculture, Ecosystems and Environment (Article accepted)	

Issue – Weed management		
Practice 10 – Optimised fallow weed control		
Description	Spray all weeds before they seed (in a fallow situation)	
Agronomic benefits	▪ Less weed pressure for subsequent cane crop, ▪ difficult to control weeds (nutgrass, itch grass and sorghum) can be controlled more cheaply with broad spectrum herbicides (glyphosate)	
Profitability	▪ Less herbicide costs in subsequent cane crop	**Certainty –** high; proven
Water quality	▪ Less overall herbicide use ▪ Less reliance on residuals and more preference for knockdown herbicides	**Certainty –** high; proven
Requirements for implementation	▪ Most growers have the required equipment	

Chapter 5: Herbert River district

5.1 Natural resource base – Herbert River region

Climate: Median monthly rainfall figures for the Herbert River district (situated around Ingham) can vary significantly from 3000mm in the Mount Spec area to 2275mm at Ingham and less than 1600mm in the Upper Stone River area. 74 per cent of the mean annual rainfall occurs from December to March (wet season) (Bureau of Meteorology 1970). The region can experience extreme natural climate variability from one year to the next.

Parts of the region are subject to flooding on an annual basis with multiple flooding events possible in some years. Soils can remain very moist to saturated for extensive periods restricting farming operations during the late January to April period in most years.

Wet periods can occur on an annual basis during the May to October period interrupting planting, fertilising and harvesting programs or having these operations carried out in less than ideal conditions, negating best practice strategies. The problem can be disastrous in la Nina years.

Soils and Topography: Isbell and Murtha (1970) studied and mapped the soils in the area at a scale of 1:1 000 000 scale. In this study area 43 soil types and seven variants were identified together with five miscellaneous mapping units. Land resource mapping was undertaken at 1:100 000 in order to compile a resource inventory appropriate for extensive land uses and regional planning.

McDonald, *et.al* (1984) categorised the Herbert River District area into seven landform patterns – mountains, hills, rises, alluvial fans, alluvial plains, beach ridge plains and tidal flats.

Sugarcane production in the region occurs on the alluvial fans and alluvial plains soils occurring on floodplains throughout the area. These floodplains generally have a low slope and gradient.

Alluvial fans soils are formed from washed material from hills and deposited at the base of these hills by channelled stream flow or sheet flow. Generally slopes between < 1-2 per cent can be found growing cane in the Herbert River area.

Alluvial plains soils can be broken down further into two categories being either creek or river derived. The alluvial plains creek derived soils are loamy earth soils formed on the levees, terraces and prior streams of creeks draining the granitic and acid volcanic hills. The exceptions are the sandy soils which have occurred from in-filled prior streams (Wilson and Baker, 1990). Generally these soils have low cation exchange capacities and low in critical nutrients for cane growth (like nitrogen, phosphorus and calcium). Sodic soils are also typically found in these areas.

The alluvial plains river derived soils are located around the Herbert and Stone Rivers and their associated tributaries (like the Trebonne, Palm, Victoria, Cattle and Gentle Annie Creeks). These soils are generally more fertile than the alluvial plains creek derived soils. Sandy loam soils are usually located on the river levees to the clay soils further away from the river systems. The clay loam - clay soils in this category usually have slopes <1 per cent, prone to waterlogging and can be difficult to manage when being farmed.

5.2 Herbert River sugar industry

Farm characteristics: Properties are generally private or family ownership but there is an increasing number being leased to other growers. Leasing is becoming more popular on the large proportion of small holdings (approximately 50ha or less) on which families struggle to make a living. The milling company Sucrogen has acquired parcels of land in the region in the past 12-18 months, intending to develop a large cane growing enterprise in the region.

Harvesting and the majority of planting are done by contractors or group-owned machinery. Most other operations are carried out with predominantly grower-owned machinery although there is some contract fertilising developing with approximately 20 per cent of the area being fertilised by contractors. There is a mix of contractors and grower-owned machinery undertaking spraying activities in the region; with contractors undertaking the majority of out of hand spraying within the region. Spray is undertaken mainly by ground rigs, however aerial spraying is undertaken when crops are out of hand stage or when field conditions do not allow ground rigs to operate (usually after significant rainfall events and prolonged wet periods).

Social attributes: There is a mix of full time farmers (being the dominant group) and part time farmers who usually have jobs within the agricultural community (as cane haulout operators, tradesmen, earthmoving plant operators or professionals) or within the mining industry (as fly in fly out mining personnel).

The full-time farmers fall into two categories, being the older growers or younger growers who manage larger parcels of land requiring full time employment. Within this group there is an ageing grower population which can have some effect on attitude to change. However, they are generally ready to accept or adopt anything that relates to new machinery/technology. For example, they are generally enthusiastic about things like GPS and the associated software but it is probable they are not maximising the potential of this type of equipment. IT skills are not advanced within the older grower ranks. The older growers in this category tend to have lower debt loadings compared to other groups of growers.

The part-time growers are predominately growers under 50 years of age and generally have farm sizes not large enough to provide a full-time income. There is some potential for this group of growers to manage larger parcels of land, however financial situations (availability to access money and existing debt loadings) and being land locked in some cases, does not allow for expansion of cane enterprise to occur. It is estimated about one third of growers in the Herbert district have other full or part-time jobs to supplement the farm income.

The average tertiary educational level of growers is low when judged against the community average. Many growers are qualified tradesmen with appropriate training and qualifications. In general growers have a wealth of agricultural and agricultural business knowledge through their on farm experiences.

Literacy levels are generally below the community average in some demographic groups; however generally improve with the younger demographic groups. Also a portion of growers have English as a second language which has its inherent difficulties when developing extension programs.

Extension services have been readily accessible by growers but they have not always grasped this opportunity. With the recent withdrawal of BSES undertaking extension activities in the Herbert, Herbert Cane Productivity Services Limited (HCPSL) has assumed the role as the major extension provider in the region. HCPSL has a staff of 11 staff, with six of the staff working in the field of extension or extension agronomy. Extension programs are well established in the region with one on one, group and mass media extension activities occurring.

Links to processing: Sucrogen (previously owned by CSR Limited) currently owns and operates both existing sugar mills within the Herbert River region. Sucrogen is owned by Wilmar, a Singaporean-based agricultural company. Sucrogen produces sugar, molasses and generate “green” power at its Herbert River milling operations. Both Macknade and Victoria Mills have the capacity of crushing in excess of five million tonnes of cane, with Victoria Mill being the largest mill in Australia and Macknade being the oldest mill in Australia.

At this stage a new mill is being proposed by North Queensland Bio-Energy Corporation for the region. This project is in its early stages of planning and development. It is proposed that this factory will commence operation in 2015. It is proposed that this factory will produce sugars, alcohols (predominately ethanol) and significant amounts of “green” electricity. This business venture will be funded by domestic and international funding; with significant grower investment already into the project.

Cropping options in the region: Wilson PR and Baker DE (1990) authored the *Soils and Agricultural Land Suitability of the Wet Tropical Coast North Queensland- Ingham Area-* QV90001. The report assessed the suitability for growing sugarcane, horticulture crops, forestry crops, maize and improved pasture.

At present sugarcane occupies approximately 62 000 hectares of the area, with the potential to increase this area further after the collapse of the MIS (management investment scheme) tree plantation businesses. There is an established forestry industry growing *Pinus caribaea* in the region; this industry was devastated by cyclone Yasi in 2011, but intends to re-establish once the crop is harvested. There also exists a small horticulture industry growing tropical fruits, melons and pumpkins.

At present sugarcane will remain the most viable option on many of the Herbert River District soils because of the prolonged water logging periods experienced and lack of suitability of other crops to grow in these areas.

5.3 Key practices for the Herbert River region

In summary, the key suite of profitable and sustainable practices for the Herbert River region and their role are as follows:

Practice	Cropping systems	Soil and water mgmt	Nutrient mgmt	Weed mgmt
1 – Green cane trash blanket	✓	✓	✓	✓
2 – End of fallow legume and weed management	✓	✓	✓	✓
3 – Legume fallow crops	✓	✓	✓	✓
4 – Maintain ground cover during a fallow	✓	✓		✓
5 – Drainage maintenance		✓		
6a) – Double disc opener planter and preformed beds		✓		
6b) - Double disc opener planter and beds formed after germination		✓		
7 – Best practice nutrient management for the wet tropics			✓	
8 – Apply optimised weed control principles				✓
9 – Timing of application to reduce weed competition				✓
10 –Upgrade herbicide application equipment				✓

These are all detailed in the following section.

Issue – Cropping systems		
Practice 1 – Green cane trash blanket (GCTB)		
Description	Retention of trash after harvesting the sugarcane crop with no pre-harvest burning (green cane) as a soil surface blanket or mulch	
Agronomic benefits	▪ Zero tillage ratoons except for sub-surface fertiliser application which results in minimum soil disturbance. ▪ Improved soil structure, better water infiltration and improved soil moisture content. ▪ Less soil erosion. ▪ Improved nutrient availability. ▪ Suppression of weed germination and growth.	
Profitability	▪ Reduced tillage with lower machinery and labour costs. ▪ Less requirement to use herbicides particularly residuals in GCTB farming systems. ▪ Less cultivation/levelling required to rectify eroded fields.	**Certainty -** high – well established in wet tropics with 97 per cent of the crop harvested green in 2007.
Water quality	▪ Reduced soil erosion and therefore particulate phosphorus and herbicides in runoff water ▪ Less herbicide use particularly residuals	**Certainty -** high – less erosion, particulate phosphorus and residual herbicides.
Requirements for implementation	▪ Fertiliser applicator with coulters or coulter/tine combination capable of subsurface application within or beside the cane row. ▪ High clearance over-the-row spray equipment particularly for vine control; contractors are available.	
Supporting information	▪ Prove B, Truong P, Evans D (1986). Strategies for controlling caneland erosion in the wet tropical coast of Queensland. Proc. Aust. Soc. Sugar Cane Technol. 8:77-84. ▪ Schroeder B, Panitz J, Linedale T, Whiteing C, Callow B, Samson P, Hurney A, Calcino D, Allsopp P (2009). SmartCane harvesting and ratoon management. BSES Limited Technical Publication TE09004. ▪ Roberston F.A., Thorburn P.J. (2007). Management of sugarcane harvest residues: consequences for soil carbon and nitrogen. Australian Journal of Soil Research, Volume 45, pp. 13-23 ▪ A.W. Wood (1986), Green cane trash management in the Herbert Valley. Preliminary results and research priorities Proceedings of the Australian Society of Sugar Cane Technologists., 1986 Conf. (1986), pp. 85–94 ▪ Thorburn P.J., Keating B.A., Robertson F.A., (2000). Long-term changes in soil carbon and nitrogen under trash	

	blanketing, Proceedings of the Australian Society of Sugar Cane Technologists. 217-224 ▪ Green cane trash blanketing; BSES Bulletin (January 1995) ▪ Prove B, Truong P, Evans D (1986). Strategies for controlling caneland erosion in the wet tropical coast of Queensland. Proceedings of the Australian Society of Sugar Cane Technologists. 8:77-84. ▪ Schroeder B, Panitz J, Linedale T, Whiteing C, Callow B, Samson P, Hurney A, Calcino D, Allsopp P (2009). SmartCane harvesting and ratoon management. BSES Limited Technical Publication TE09004.

Fertilising sub-surface with stool splitter in green cane trash blanket – Wet Tropics

<table>
<tr><td colspan="3">Issue – Cropping systems</td></tr>
<tr><td colspan="3">Practice 2 – End of fallow legume and weed management</td></tr>
<tr><td>Description</td><td colspan="2">Spray out legumes and also problem weeds and vines before they seed.</td></tr>
<tr><td>Agronomic benefits</td><td colspan="2">▪ Release of nitrogen from legumes is slowed when killed by chemical spray resulting in a reduction in potential leaching losses, when the legume incorporation is delayed.
▪ Reduction in the weed seedbank and weed pressure throughout the crop cycle.
▪ Delays introduction of cultivation equipment into the paddock reducing window of opportunity for erosion.
▪ Reduced potential for cultivation at inappropriate moisture content creating large lumps resulting in excessive cultivation.
▪ Attempt to leave legume stubbles on the surface as long as possible before incorporation to prevent N loss pathways from occurring.</td></tr>
<tr><td>Profitability</td><td>▪ Less nitrogen loss.
▪ Reduced N fertiliser requirement for plant cane
▪ Less herbicide in subsequent crops.
▪ Reduced cultivation costs and potential for erosion.</td><td>Certainty - medium; proven</td></tr>
<tr><td>Water quality</td><td>▪ No flush of legume N into the system when legumes are left unincorporated and incorporation is delayed.
▪ Less overall herbicide use.
▪ Reduced potential for soil erosion.</td><td>Certainty
▪ Low: N
▪ Medium – high: chemicals
▪ Low: erosion</td></tr>
<tr><td>Requirements for implementation</td><td colspan="2">Required equipment is available on most farms.</td></tr>
<tr><td>Supporting information</td><td colspan="2">▪ Van Grieken M.E., Webster A.J., Coggan A, Thorburn P, Biggs J 2010. Agricultural management practices for water quality improvement in the Great Barrier Reef Catchments. CSIRO: Water for a Healthy Country National Research Flagship.
▪ Hurney A, Schroeder B, Calcino D, Allsopp P (2008). Smart Cane fallow and land management. BSES Limited Technical Publication TE08009.
▪ Garside A.L., Bell M (2006). Sugar Yield Decline Joint Venture Phase 2 (July 1999 – June 2006). Final report, SRDC, Project JVD002.</td></tr>
</table>

Direct drill legumes in fallow

Issues– Soil, water and nutrient management	
Practice 3 – Legume fallow crop	
Description	Legume fallows are an ideal method to suppress weed populations, while providing a cover crop to minimise soil losses. Problematic weeds should be controlled prior to any attempt to undertake a legume fallow. Plant legumes into – (a) newly formed beds in fully cultivated soil; (b) existing beds (or mounds) following zonal tillage; (c) direct-drill (zero tillage) into existing beds (or mounds). Note - Where cultivation is employed, the focus should be on minimum cultivation to limit adverse effects on soil structure, biology and organic matter. Used primarily in areas that does not regularly flood over the summer period.
Agronomic benefits	▪ Good fallow management leads to lower weed pressure in plant and ratoon crops. ▪ Improved soil health through better soil biology provided sugarcane is fully removed from the fallow. ▪ Nitrogen mineralisation resulting in possible reduction of N fertiliser inputs.

	▪ Opportunity to reduce weed seedbank particularly of problem weeds (e.g. Guinea grass) with judicial use of either residual or knockdown herbicides leading to reduced use of residual chemicals in GCTB ratoon crops. ▪ Breaking monoculture can help in breaking cycle of soil born pathogens. ▪ Planting legumes on mounds will result in better growth as this minimises the effects of water logging.	
Profitability	▪ Management costs increase with degree of cultivation and herbicide inputs. ▪ Fertiliser N inputs will be reduced in the plant crop but usually not significantly as legume crops are generally poor to average in the Herbert. Herbicide inputs should be reduced in ratoon crops. ▪ Plant crop yields increased following a fallow relative to ploughout/replant (PORP).	**Certainty** ▪ Low: nitrogen ▪ Medium: ratoon herbicides
Water quality	▪ Reduced soil erosion and particulate phosphorus in runoff water. ▪ Reduced residual herbicide use in ratoons. ▪ May be excess N to crop requirements particularly early in plant crop.	**Certainty** ▪ Low – high: erosion depending on cultivation level. ▪ Medium – high: herbicides. ▪ Low for nitrogen if N flush from legumes.
Requirements for implementation	Bedformer is required. Legume planter required - possible to hire in most districts. Note - This practice is applicable to all row spacing's	
Supporting information	▪ Garside A.L., Bell M.J. (2001). Fallow legumes in the Australian sugar industry: Review of recent research findings and implications for the sugar cane cropping system. Proceedings of the Australian Society of Sugar Cane Technologists,23:230-235 ▪ Garside A.L., Bell M.J. (2011). Growth and yield responses to amendments to the sugarcane monoculture: effects of crop, pasture and bare fallow breaks and soil fumigation on plant and ratoon crops. *Crop and Pasture Science* 62, 396 – 412. ▪ Pankhurst C.E., Stirling G.R., Magarey R.C., Blair B.L., Holt J.A., Bell M.J., Garside A.L. (2005). Quantification of the effects of rotation breaks on soil biological properties and their impact on yield decline in sugar cane, Soil Biology and Biochemistry, Volume 37, pp. 1121-30. ▪ Roebeling P.C., Webster A.J., Biggs J, Thorburn P (2007). Financial-economic analysis of current best management practices for sugarcane, horticulture, grazing and forestry industries in the Tully-Murray	

	catchment. CSIRO: Water for a Healthy Country National Research Flagship. CSIRO Sustainable Ecosystems, Townsville, Australia (p. 48) (Report explains practices related to legume mixed cropping) ▪ Loeskow N, Cameron T, Callow B (2006). Grower Case Study on Economics of an Improved Farming System. Proceedings of the Australian Society of Sugar Cane Technologists, Volume 28. ▪ Garside A.L., Watters T.S., Berthelsen J.E., Sing N.J., Robotham B.G., Bell M.J. (2004). Comparisons between conventional and alternative sugarcane farming systems which incorporate permanent beds, minimum tillage, controlled traffic and legume fallows Proceedings of the Australian Society for Sugar Cane Technologists 26 (CD-ROM). ▪ Poggio M, Hanks M (2007). Fallow management calculating the profitability of different fallow management options. The Sugar Research and Development Corporation, Queensland ▪ Hurney A, Schroeder B, Calcino D, Allsopp P (2008). SmartCane fallow and land management. BSES Limited Technical Publication TE08009. ▪ Garside A.L., Bell M (2006). Sugar Yield Decline Joint Venture Phase 2 (July 1999 – June 2006). Final report, SRDC, Project JVD002.

Soybean fallow – Herbert

Issues – Soil, water and nutrient management		
Practice 4 – Maintain ground cover during a fallow		
Description	Spray out of old ratoons with a non-residual chemical combined with either retention of GCTB with/without direct drilled cover crop; or zonal tillage plus cover crop; or full cultivation plus cover crop. Where cultivation is employed, the focus should be on minimum cultivation to limit adverse effects on soil structure, biology and organic matter.	
Agronomic benefits	▪ Maintaining ground cover during fallow results in less soil erosion. ▪ Effective killing of old ratoon stubble using chemical spray-out breaks monoculture increases soil organic matter and improves soil health over long term.	
Profitability	▪ Less cultivation/levelling required repairing eroded fields. ▪ Plant crop yields increased following a fallow relative to ploughout/replant (PORP).	**Certainty -** high to low depending on the degree of cultivation
Water quality	Reduced soil erosion, herbicide and particulate phosphorus in runoff water.	**Certainty -** high to low depending on the degree of cultivation
Requirements for implementation	Most growers have the required equipment or can hire equipment/contractors.	
Supporting information	▪ A.W. Wood (1986),Green cane trash management in the Herbert Valley. Preliminary results and research priorities, Proc. Aust. Soc. Sugar Cane Technol., 1986 Conf. (1986), pp. 85–94 ▪ Thorburn P.J., Keating B.A., Robertson F.A., Wood A.W. (2000). Long-term changes in soil carbon and nitrogen under trash blanketing, Proceedings of the Australian Society of Sugar Cane Technologists.217-224 ▪ Green cane trash blanketing; BSES Bulletin (Jan 1995) ▪ Bell M.J., Halpin N.V., Garside A.L., Moody P.W., Stirling G.R., Robotham B.J. (2003) Evaluating combinations of fallow management, controlled traffic and tillage options in prototype sugarcane farming systems at Bundaberg. Proceedings of the Australian Society of Sugar Cane Technologists: 16 ▪ Hurney A, Schroeder B, Calcino D, Allsopp P (2008). SmartCane fallow and land management. BSES Limited Technical Publication TE08009. ▪ Hogarth D.M., Allsopp P (2000). Manual of cane growing. BSES, Indooroopilly, Australia.	


Forming raised beds on wide rows – Wet Tropics

Issue -Soil and water management	
Practice 5 – Drainage maintenance	
Description	Surface drainage – Land levelling to remove depressions and pondage areas; elimination of micro-scale water erosion furrows to reduce sediment export; lower and re-grass headlands to improve surface runoff and sediment trapping efficiency. Subsurface drainage – open drain maintenance and revegetation to enhance water removal and minimise sediment loads. Maintenance of existing subsurface drainage pipes to maintain efficiency and install new systems where required.
Agronomic benefits	Reduce water-logging effect resulting in better crop growth, more effective nutrient use, reduced greenhouse gas losses and improved yield.

Profitability	Increased crop yield. Reduces loss of N (both applied and mineralised) due to de-nitrification	**Certainty - h**igh; proven
Water quality	Reduced risk of sediment, nutrient and chemical losses with reduced runoff and sediment loads.	**Certainty -** low - medium
Requirements for implementation	Most growers either have equipment or can hire contractors.	
Supporting information	▪ Roth C.H., Visser F (2003). Quantifying and managing sources of sediments and nutrients in low-lying canelands. CSIRO Land and Water, Technical Report 52/03, December 2003. (Report analyses current cane farming systems and further refines the current management practices for reducing sediment and nutrient export from low lying cane lands prone to frequent runoff). ▪ McKergow L.A., Prosser I.P., Greyson, R.B., Heiner D (2004). Performance of grass and rainforest riparian buffers in the wet tropics, Far North Queensland 2 Water Quality. Australian Journal of Soil Research, Volume 42, pp. 485-98. (Article is on management practices for reducing sediment loads) ▪ Prosser I, Karssies L (2001). Designing filter strips to trap sediment and attached nutrient', *River and Riparian Land Management technical guideline*. Land and Water Australia, Canberra (Article is on management practices for reducing sediment loads) ▪ Carluer N,, Tournebize J, Gouy V, Margoum C, Vincent B, Gril JJ (2011) , Role of buffer zones in controlling pesticides fluxes to surface waters. Procedia Environmental Sciences 9, 21 – 26. (Article is on management practices for reducing sediment loads) ▪ Allen D.E., Kingston G, Rennenberg H, Dalal R.C., Schmidt S (2010). Effect of nitrogen fertilizer management and waterlogging on nitrous oxide emission from subtropical sugarcane soils. Agriculture, Ecosystems & Environment, 136, Pages 209-217 (Paper looks into denitrification losses and suggests management options for reducing losses from denitrification). ▪ Bryant K, Philip S, Hughes K, Willis R (2012) Mapping of environmental characteristics important for Reef water quality Burdekin and Mackay Whitsunday priority catchment: Assessment methodology, Land Resource Assessment, Department of Science, Information Technology, Innovation and the Arts, Brisbane. (Report provides information and maps of the natural landscape features (or environmental characteristics) that influence the movement of contaminants off-property via surface water transport processes) Hurney A, Schroeder B, Calcino D, Allsopp P (2008). SmartCane fallow and land management. BSES Limited Technical Publication TE08009. ▪ Reghenzani J.R., Roth C.H. (2006). Best practice surface drainage for low-lying sugarcane lands Herbert district.	

	BSES Limited Technical Publication TE 6004. ▪ Hogarth D.M., Allsopp P (2000). Manual of cane growing. BSES, Indooroopilly, Australia. ▪ Waring M (2005). Interpreting Laser Landforming Designs. HCPSL Publication.

Issue – Soil and water management		
Practice 6(a) – Double disc opener planter (DDOP) and pre formed beds/mound planting (MP)		
Description	Minimum tillage planting into raised beds formed pre-fallow on wide row spacing.	
Agronomic benefits/problems	▪ Minimises soil disturbance, opportunity for earlier planting, less machinery operations. ▪ Reduces soil compaction due to less machinery passes. ▪ Reduced weed growth due to reduced soil disturbance. Note - Difficulties can be experienced on heavy clay soils with adequate soil to sett contact leading to poor cane germination and establishment in the region.	
Profitability	▪ Reduced risk of weed control costs. ▪ reduced risk of sediment losses ▪ Less tractor operations and time.	**Certainty** - unknown but potentially lower than Practice 6(b).
Water quality	▪ Unknown although potentially slightly lower erosion loss than conventional row spacing in ratoons. ▪ Planting into permanent preformed beds will have a positive environmental impact in relation to sediment and nutrient losses.	**Certainty -** unknown but very low erosion potential. Trials needed.
Requirements for implementation	DDOP/ MP capability.	
Addendum	DDOP plus mounds or hills can be used for any row spacing.	
Supporting information	▪ Poggio M, Morris E, Reid N, DiBella L (2007) 'Grower group case study on new farming practices in the Herbert', Proceedings of the Conference of the Australian Society of Sugar Cane Technologists. Volume 29. (Report focuses on economic analysis of the new farming system with a legume crop rotation) ▪ Garside A.L. (2005).The potential for permanent raised beds in sugarcane cropping systems. In Roth C.H., Fischer R.A. and Meisner C.A. (EDS.) Evaluation and performance of permanent raised bed cropping systems in Asia, Australia and Mexico. Proceedings of ACIAR Workshop, Griffith, NSW, Australia, March 1 – 3, 2005. pp. 154 – 161.	

	▪ Garside A.L. (2006). Management of the interface between sugarcane cycles in a permanent bed, controlled traffic farming system. Proceedings of the Conference of the Australian Society of Sugar Cane Technologists. 118 ▪ Garside A.L., Bell M.J., Robotham B.J. (2009).Row spacing and planting density effects on the growth and yield of sugarcane. 2. Strategies for the adoption of controlled traffic. Crop and Pasture Science, 60: 544 – 554. ▪ Halpin N.V., Cameron T, Russo PF (2008). Economic Evaluation of Precision Controlled Traffic Farming in the Australian Sugar Industry: A Case Study of an Early Adopter. Proceedings of the Conference of the Australian Society of Sugar Cane Technologists. Volume 30. ▪ Tullberg J.N., Zeibarth L.J., Yuxia L (2001). Traffic and Tillage effects on run off, Australian Journal of Soil Research, Volume 39, pp. 249-57. ▪ Stephanie A.S., Jenkins A, Lines-Kelly R (2009). Saving Soil ~ A landholder's guide to preventing and repairing soil erosion, Technical publication by NSW DPI and Northern Rivers Catchment Management Authority Implementing an efficient and improved farming system (www.reefcatchments.com.au) ▪ Van Grieken M.E., Webster A.J., Coggan A, Thorburn P, Biggs J (2010). Agricultural Management Practices for Water Quality Improvement in the Great Barrier Reef Catchments. CSIRO: Water for a Healthy Country National Research Flagship. ▪ Calcino D, Schroeder B, Hurney A, Allsopp P (2008). SmartCane plant cane establishment and management. BSES Limited Technical Publication TE08010. ▪ Garside A.L., Bell M (2006). Sugar Yield Decline Joint Venture Phase 2 (July 199 – June 2006). Final report, SRDC, Project JVD002. ▪ Hurney A.P. and Skocaj D.M. (2010). Assessment and possible adaption of the double-disc opener planter technique in the wet tropics. Proc. Aust. Soc. Sugar Cane Technol. 32:110-118.

Issue – Soil and water management	
Practice 6(b) – Mound planting and double disc opener planter (DDOP) and beds formed post germination	
Description	Minimum tillage planting on wide rows into a level or slightly mounded soil surface with final bed /mound profile formed post-germination. In some instances raised beds formed for a legume fallow will be levelled (through zonal tillage) at the end of the fallow prior to planting.
Agronomic benefits/problems	▪ Depth of anchorage of the sugarcane sett in soil is greater than with practice 5(a) reducing propensity to lodge and stool tip.

	▪ Minimum soil disturbance at planting. ▪ Increased cultivation relative to Practice 5(a). ▪ Reduces soil compaction compared to full cultivation ▪ Reduced risk of nutrient, sediment and chemical losses	
Profitability	▪ Reduced lodging and stool tip ▪ May lead to higher yields and longer ratoon cycle than Practice 6(a).	**Certainty -** unknown but potentially higher than Practice 6(a).
Water quality	▪ Unknown although potentially slightly lower erosion loss than conventional planting and narrow row spacing in ratoons	**Certainty -** unknown but very low erosion potential. Trials needed.
Requirements for implementation	DDOP/MP capability and non-conventional hilling up equipment.	
Addendum	MP/DDOP plus mounds or hills can be used for any row spacing	
Supporting information	▪ Calcino D, Schroeder B, Hurney A, Allsopp P (2008). SmartCane plant cane establishment and management**.** BSES Limited Technical Publication TE08010. ▪ Garside A.L., Bell M (2006). Sugar Yield Decline Joint Venture Phase 2 (July 199 – June 2006). Final report, SRDC, Project JVD002. ▪ Hurney A.P. and Skocaj D.M. (2010). Assessment and possible adaption of the double-disc opener planter technique in the wet tropics. Proc. Aust. Soc. Sugar Cane Technol. 32:110-118.	

Issue –Nutrient management		
Practice 7 –Best practice nutrient management		
Description	▪ Adopt nitrogen and phosphorus application strategies as outlined in the SIX EASY STEPS principles and guidelines for the wet tropics	
Agronomic benefits	▪ Nitrogen and phosphorus fertiliser inputs matched to crop requirements and adjusted for non-fertiliser sources.	
Profitability	▪ Profitability will be similar to previous grower nutrient management practices for N and P under the prevailing	**Certainty -** medium - high

	environmental conditions.	
Water quality	▪ Potential for lower N losses where inputs have been reduced under the SIX EASY STEPS guidelines. P losses will be dependent on sediment losses.	▪ **Certainty -** medium - high
Requirements for implementation	▪ Fertiliser applicator suitable for sub-surface or liquid applications either within or beside the row under a GCTB.	
Supporting information	▪ Calcino D, Schroeder B, Hurney A, Allsopp P (2008). SmartCane plant cane establishment and management**.** BSES Limited Technical Publication TE08010. ▪ Schroeder B, Wood A, Moody P, Stewart R, Panitz J, Benn J (2007). Soil-specific nutrient management guidelines for sugarcane production in the Johnstone catchment**.** BSES Limited Technical Publication TE07001. ▪ Schroeder B, Wood A, Hurney A, Panitz J Calcino D (2008). Accelerating the adoption of best-practice nutrient management: Wet Tropics. Short course manual, BSES Limited, Bundaberg. ▪ Schroeder B, Hurney A, Wood A, Moody P, Calcino D, Cameron T (2009a). Alternative nitrogen management strategies for sugarcane production in Australia: The essence of what they mean. Proc. Aust. Soc. Sugar Cane Technol. 31:93-103. ▪ Schroeder B, Panitz J, Linedale T, Whiteing C, Callow B, Samson P, Hurney A, Calcino D, Allsopp P (2009b). SmartCane harvesting and ratoon management**.** BSES Limited Technical Publication TE09004. ▪ Schroeder B, Wood A, Park G, Panitz J, Stewart R (2009c). Validating the 'Six Easy Steps' nutrient guidelines in the Johnstone catchment. . Proc. Aust. Soc. Sugar Cane Technol. 31:117-185. ▪ Skocaj D, Hurney A, Schroeder B.L. (2012). Validating the 'Six Easy Steps' nitrogen guidelines in the wet tropics. Proc. Aust. Soc. Sugar Cane Technol. 34 (USB). ▪ Schroeder B.L., Wood A.W., Moody P.W., Bell M.J., Garside A.L. (2005). Nitrogen fertiliser guidelines in perspective. Proceedings of the Australian Society of Sugar Cane Technologists.,27: 291-304 ▪ Van Grieken M.E., Webster A.J., Coggan A, Thorburn P, Biggs J (2010). Agricultural Management Practices for Water Quality Improvement in the Great Barrier Reef Catchments. CSIRO: Water for a Healthy Country National Research Flagship. ▪ Salter B, Schroeder B.L., Wood A.W. Panitz J.H., Park G (2008). The use of replicated strip trials for demonstrating the effectiveness of different nutrient management strategies for sugarcane. Proceedings of the Australian Society of Sugar Cane Technologists.,30: 361 ▪ Wood A.W. Schroeder B.L., Hurney A.P., Salter B, Panitz J.H. (2008). Research aimed at enhancing nitrogen management guidelines for the six easy steps program. Proceedings of the Australian Society of Sugar Cane Technologists., 30: 362 ▪ Wood A.W., Schroeder B.L., Dwyer R (2010). Opportunities for improving the efficiency of use of nitrogen	

	fertiliser in the Australian sugar industry. Proceedings of the Australian Society of Sugar Cane Technologists., 32: 221-231 ▪ Schroeder B.L., Wood A.W., Sefton M, Hurney A.P., Skocaj D.M., Stainlay T, Moody P.W. (2010). District Yield Potential: An appropriate basis for Nitrogen guidelines for sugarcane production. Proceedings of the Australian Society of Sugar Cane Technologists.,32: 193 ▪ Schroeder B.L., Wood A.W., Moody, P.W., Panitz J.H., Agnew J.R., Sluggett R.J., Salter B (2006). Delivering nutrient management guidelines to growers in the central region of the Australian sugar industry. Proceedings of the Australian Society of Sugar Cane Technologists.,28: 142-154 ▪ Moody P.W., Panitz J.H. (2005). Sustainable Nutrient Management – Delivering the message to the Australian Sugar Industry. BSES, CSR, and the Department of Natural Resources and Mines; Queensland ▪ Sugarcane farmer of the year reducing run-off, Reef Water Quality Plan, Measuring Success; http://www.reefplan.qld.gov.au/measuring-success/case-studies.aspx#sugarcane ▪ Chapman L.S. (1994), Fertiliser N management in Australia. Proceedings of the Australian Society of Sugar Cane Technologists. 20: 84-92

Fertilising sub-surface with stool splitter in green cane trash blanket – Wet Tropics

Issue – Weed management		
Practice 8–Applying optimised weed control principles		
Description	Focus on reducing the seedbank for problem weeds during fallow and plant crops. To achieve this appropriate use of both residuals and non-residuals herbicides should be used during this phase. If residuals are used during the fallow or plant crop phases, they will be more effective as they can be applied to exposed soil rather than soil masked by a GCTB. Residual herbicides could be either eliminated or severely limited for the weed control program in ratoon crops with a thick/dense GCTB.	
Agronomic benefits	Increased efficacy of herbicides and better weed control.	
Profitability	Increased efficacy of herbicides resulting in lower herbicide use overall. Lower herbicide costs in ratoon crops with optimised use	**Certainty** - high

	or possible elimination of residuals	
Water quality	Less overall residual herbicides used	**Certainty -** high
Requirements for implementation	Most growers have required equipment but will need access to high clearance over-the-row spray equipment. Process will be limited by a ploughout/replant system of sugarcane production. Greater availability of effective and economically viable alternative chemicals. High crop yields which contribute to sufficient trash blanket cover for effective weed suppression.	
Addendum	Linked to Practices 3 and 4.	
Supporting information	▪ Silburn D.M., Foley J.L., and deVoil R.C. (2011). Managing runoff of herbicides under rainfall and furrow irrigation with wheel traffic and banded spraying. Agriculture, Ecosystems and Environment. (Article in press). ▪ Masters B, Rohde K, Gurner N, Reid D (2012) Reducing the risk of herbicide runoff in sugarcane farming through controlled traffic and early-banded application. Agriculture, Ecosystems and Environment (Article accepted) ▪ Callow B, Fillols E, Wilcox T (2010). Weed Management Manual. BSES Limited Technical publication MN10004. ▪ O'Grady T, Sluggett R (2000). Herbicide Manual. Bureau of Sugar Experiment Stations, Indooroopilly. ▪ Hurney A, Schroeder B, Calcino D, Allsopp P (2008). SmartCane fallow and land management. BSES Limited Technical Publication TE08009.	

Issue – Weed management	
Practice 9–Timing of application to reduce weed competition	
Description	▪ Apply herbicides to control weeds for the initial 12 weeks after planting in the plant crop as crop loss is greatest from weed competition during this period. Residuals will probably be a better option for an effective result. ▪ The impact of weed competition is significantly reduced in ratoon crops because of the more rapid sugarcane establishment phase than in the plant crop and due to the presence of the green cane trash blanket (GCTB). An additional knockdown herbicide application may be required during the establishment phase of ratoon fields harvested early in the season if cane growth is slower due to cold/wet conditions. ▪ Time the application of chemicals to try and avoid intensive rain events and the risks of off site losses of chemicals and poor weed control
Agronomic benefits	Increased yields and longevity of ratoons.

Profitability	Increased yields	**Certainty -** medium - high
Water quality	Limited, although herbicide use should be reduced in the long term	**Certainty -** low - medium
Requirements for implementation	Most growers have required equipment.	
Supporting information	▪ Van Grieken M.E., Webster A.J., Coggan A, Thorburn P, Biggs J (2010). Agricultural Management Practices for Water Quality Improvement in the Great Barrier Reef Catchments. CSIRO: Water for a Healthy Country National Research Flagship. ▪ Callow B, Fillols E, Wilcox T (2010). **Weed Management Manual**. BSES Limited Technical publication MN10004. ▪ O'Grady T, Sluggett R (2000). **Herbicide Manual.** Bureau of Sugar Experiment Stations, Indooroopilly. ▪ Calcino D, Schroeder B, Hurney A, Allsopp P (2008). **SmartCane plant cane establishment and management.** BSES Limited Technical Publication TE08010. ▪ Schroeder B, Panitz J, Linedale T, Whiteing C, Callow B, Samson P, Hurney A, Calcino D, Allsopp P (2009). **SmartCane harvesting and ratoon management.** BSES Limited Technical Publication TE09004.	

Issue – Weed management		
Practice 10 – Upgrade herbicide equipment		
Description	Use equipment suitable for the job such as appropriate nozzles, air induction nozzles, flow rate controllers with monitoring equipment, etc	
Agronomic benefits	Improved weed control due to more effective coverage and rate.	
Profitability	Purchase costs will be offset by better weed control and less chemical wastage.	**Certainty -** unknown; trials needed
Water quality	More accurate placement and rate of herbicide should lead to a reduced risk of offsite movement.	**Certainty –** unknown; trials needed
Requirements for implementation	New equipment and training in its use.	
Supporting information	▪ Callow B, Fillols E, Wilcox T (2010). Weed Management Manual. BSES Limited Technical publication MN10004.	

	▪ O'Grady T, Sluggett R (2000). Herbicide Manual. Bureau of Sugar Experiment Stations, Indooroopilly. ▪ Schroeder B, Panitz J, Linedale T, Whiteing C, Callow B, Samson P, Hurney A, Calcino D, Allsopp P (2009). SmartCane harvesting and ratoon management. BSES Limited Technical Publication TE09004.

Chapter 6: Wet Tropics region

6.1 Natural resource base – Wet Tropics region

Background: Sugarcane production on the coastal lowlands of the Wet Tropics region is carried out between Cardwell in the south and Cape Tribulation in the north. The sugarcane production system is primarily a rain-fed one and consequently productivity can be variable between years. However, because of the high rainfall, a feature of the influence of rainfall on cane production within the region is that productivity is generally highest in the drier years and lowest in wetter years.

The region is also a major production area for bananas and papaws, also has a small but significant tropical fruits industry, and a fledgling cocoa industry.
There are five main river catchments within the region:

- Tully and Murray rivers
- North and South Johnstone rivers
- Russell and Mulgrave rivers
- Barron River
- Mossman and Daintree rivers.

These rivers combined with the many creeks within the region contribute to the broken terrain. Because of the high rainfall, runoff or drainage of water from the landscape is a natural consequence. Drainage water from the various farming enterprises, with potential to contain nutrients and other chemicals, is carried into the marine environment via this network of creeks and rivers.

Aerial view of part of Tully district

Climate: The major climatic features of the Wet Tropics region are summarised as follows:

- High rainfall area with the majority of rain received during December to April (wet season). Annual rainfall ranging from 3000–4000mm is recorded between Fishery Falls and Tully with annual rainfall ranging from 2000–3000 being recorded across the rest of the region
- Experiences extreme natural climate variability from one year to the next which influences crop yields and farming practices
- Combination of high rainfall and poor distribution particularly during early crop growth result in poor sugarcane crop yields
- Below average rainfall usually results in above average crop yields
- Storms in November – March can result in erosive events
- Parts of the region are subject to flooding on an annual basis with multiple flooding events possible in some years
- Soils remain very moist to saturated for extensive periods restricting farming operations during the late January to March period in most years
- Wet periods occur on an annual basis during the May to October period interrupting planting, fertilising and harvesting programs or having these operations carried out in less than ideal conditions, negating best practice strategies. The problem is disastrous in a la Nina year.

Soils and topography: The soils of the wet tropical coastal lowlands have been mapped by CSIRO Division of Soils at 1:50 000 scale and are described in four survey reports, Murtha (1986, 1989), Canon *et al* (1992) and Murtha *et al* (1994). The classical wet tropical soil has kaolin dominant clays and low base status. A total of 96 soil series have been identified on the wet tropical coast (Murtha and Smith, 1994). The majority of the soils are formed on alluvium. Soil parent material in the upland country include granite, basalt and metamorphic and most streams carry deposits from all three parent materials. The majority of sugarcane is grown on the alluvial soils on the coastal floodplains which generally have a low slope (<two per cent).

Soils of basaltic, granitic and metamorphic origin are found on the lower slopes of the ranges to the west of the floodplains. These soils are either formed *in situ* or on alluvial fans. The majority of the fan slopes are short with two–five per cent slopes but there are some on slopes as low as one per cent. Some of these soils, particularly the basalts, are cultivated on relatively steep slopes (>five per cent) which can be subject to soil erosion if not managed appropriately. Fortunately this problem has been alleviated by the adoption of the green cane trash blanket system of cropping (GCTB). There is a relatively small area of swamp and beach ridge soils which are relatively flat.

Soil texture covers the range from coarse to fine even on the sloping land. The terrain is broken by the many creeks, gullies and rivers within the region. Most soils are characterised by good to high internal drainage and low soil water holding capacities. They remain in a saturated/waterlogged condition for extensive periods during the year. However when the rain ceases, these soils drain rapidly.

Wet Tropics sugar industry

Farm characteristics: Farms in the Tully mill district tend to have more area and consequently paddock sizes are larger than the rest of the region. The landscape in this mill district is not as broken and there is still room for industry expansion. There is a higher proportion of fallowing in this district which is linked to the larger farm size. The other cane growing districts within the region have adopted the ploughout-replant system with a relatively low adoption of fallow as part of the crop cycle unless the farms are large.

Properties are generally private or family ownership but there is an increasing number being leased to other growers particularly in the Mossman, Mulgrave, Babinda and Innisfail districts. Leasing is becoming more popular on the large proportion of small holdings (approximately 50ha or less) on which families struggle to make a living. The milling companies, Tully Sugar Limited and MSF Sugar Limited, also operate large cane-growing enterprises.

Harvesting and the majority of planting are done by contractor or group-owned machinery. Most other operations are carried out with predominantly grower-owned machinery although there is some contract fertilising developing. Spraying for vines with high clearance machines is mainly carried out by contractors.

Social attributes: The majority are full time farmers but there is an ageing grower population which can have some effect on attitude to change. However, they are generally ready to accept or adopt anything that relates to new machinery/technology. For example, they are generally enthusiastic about things like GPS and the associated software but it is probable they are not maximising the potential of this type of equipment. It is suggested that IT skills are not advanced within the grower ranks.

Many growers have second jobs in the region in which they live or as fly in fly out to the mining industry. For example, it is estimated well over half the growers in the Innisfail district have other full- or part-time jobs. As a result, farm management often does not receive the input required.

The average educational level of growers is low when judged against the community average. While many are qualified tradesmen, a very small percentage of growers have tertiary qualifications. Literacy levels are probably below the community average. A significant proportion of growers have English as a second language.

Extension services have been readily accessible to growers but they have not always grasped this opportunity. Accessibility to extension services may deteriorate in view of the recent decision by BSES Limited to withdraw from providing extension services via direct contact with growers.

Links to processing: There are four mills processing cane: Tully, South Johnstone, Mulgrave (near Gordonvale) and Mossman. There has been a reduction in the milling capacity of MFS Sugar Limited in recent years with the closure of Mourilyan mill after cyclone Larry in 2006 and Babinda mill after cyclone Yasi in 2011. This has not had an impact on season length in the South Johnstone and Mulgrave mill areas (also owned by MFS Sugar Limited) at this stage because crops have been low yielding in recent years. An increase in season length could have an adverse impact on farmer practices.

There is likely to be a potential increase in the sugarcane production area in the Tully, South Johnstone and Mulgrave mill areas over the next couple of years. Most of the area planted to tree plantations as part of the management investment schemes is being returned to sugarcane production following the collapse of these schemes in the region. This may have an impact on season length if crushing capacity is limiting.

There has also been a decline in harvesting capacity in most mill areas in recent years. This has resulted from the combined effect of low crop yields affecting profitability and the high cost of equipment upgrades. This could also adversely affect season length at some stage because of the increase in tonnage to be harvested by each harvester.

There have been good links between the grower, harvesting contractor and miller in the past. For example, clean cane bonus incentive schemes have been operating at Tully and Mulgrave mills. It is not realistic to comment on future relationships between the processing and growing side at this stage as ownership or controlling interest at all mills in the wet tropics has changed for the 2012 season and current arrangements may change.

Green cane harvesting: More then 97 per cent of the sugarcane crop was harvested green in north Queensland in 2007 (Schroeder *et al*., 2009). The majority of fields ratooned following a green harvest use a green cane trash blanket (GCTB) system as the method of cane production. This has been shown to increase soil carbon (Wood, 1991). Modelling studies on data from GCTB trials indicated that once long-term equilibrium of soil carbon and nitrogen was attained, there would be sufficient mineralisation of trash N to enable fertiliser N inputs to be reduced (Robertson and Thorburn, 2000).

Recent studies have shown soil carbon and nitrogen were increased after 15 years of GCTB. The response to fertiliser N was similar for cane grown in long-term burnt or GCTB systems. This indicates N rates should not be reduced following long-term adoption of GCTB at this stage (Hurney and Schroeder, 2012). A longer equilibration phase appears to be required.

Further reading:

- Cannon M.G., Smith C.D., Murtha G.G. (1992). Soils of the Cardwell-Tully area, north Queensland. CSIRO Aust. Div. Soils Divl. Rep No. 115.
- Hurney A.P., Schroeder B.L. (2012). Does prolonged green cane trash retention influence nitrogen requirements of the sugarcane crop in the wet tropics. Proceedings of the Australian Society of Sugar Cane Technologists, 34: (USB stick)
- Murtha G.G. (1986). Soils of the Tully-Innisfail area, north Queensland. CSIRO Aust. Div. Soils Divl. Rep No. 82.

- Murtha G.G. (1989). Soils of the Mossman-Cape Tribulation area, north Queensland. CSIRO Aust. Div. Soils Divl. Rep No. 102.
- Murtha G.G., Cannon M.G., Smith C.D. (1994). Soils of the Babinda-Cairns area, north Queensland. CSIRO Aust. Div. Soils Divl. Rep No. 123.
- Murtha G.G., Smith C.D. (1994). Key to the soils and land suitability of the wet tropical coast, Cardwell-Cape Tribulation. CSIRO Aust. Div. Soils Divl. Publication.
- Robertson F.A., Thorburn P.J. (2000). Trash management – Consequences for soil carbon and nitrogen. Proceedings of the Australian Society of Sugar Cane Technologists, 22, 225-229.
- Schroeder B, Panitz J, Linedale T, Whiteing C, Callow B, Samson P, Hurney A, Calcino D, Allsopp P (2009). SmartCane harvesting and ratoon management**.** BSES Limited Technical Publication TE09004.
- Wood A.W. (1991). Management of crop residues following green cane harvesting of sugarcane in north Queensland. Soil and Tillage Research 20:69-85.

Green cane – Wet Tropics

6.3 Key practices for the Wet Tropics region

In summary, the key suite of profitable and sustainable practices for the Wet Tropics Region and their role are as follows:

Practice	Cropping Systems	Soil & Water Mgt	Nutrient Mgt	Weed Mgt
1 – Green cane trash blanket	✓	✓	✓	✓
2 – End of fallow legume and weed management	✓	✓	✓	✓
3 – Maintain ground cover during a fallow	✓	✓	✓	✓
4 – Reduced tillage	✓	✓		✓
5 – Drainage maintenance		✓		
6 – Minimum till planting		✓		
7 – Nutrient rate and application			✓	
8 – Nutrient timing, placement and rainfall			✓	
9 – Weed control accuracy, application, timing and evaluation				✓
10 – Focus on weed control in fallow and plant cane				✓
11 –Upgrade herbicide application equipment				✓

These are all detailed in the following section.

Soybeans planted on raised beds on wide rows in wet season - Tully

<table>
<tr><td colspan="3">Issue – Cropping systems</td></tr>
<tr><td colspan="3">Practice 1 – Green cane trash blanket (GCTB) System</td></tr>
<tr><td>Description</td><td colspan="2">Retention of trash after harvesting the sugarcane crop with no pre-harvest burning (green cane) as a soil surface blanket or mulch</td></tr>
<tr><td>Agronomic benefits</td><td colspan="2">▪ Zero tillage ratoons except for sub-surface fertiliser application which results in minimum soil disturbance.
▪ Improved soil structure, better water infiltration and improved soil moisture content.
▪ Less soil erosion.
▪ Improved nutrient availability.
▪ Suppression of weed germination and growth.
▪ Increase in soil organic carbon but no indication that fertiliser N inputs can be reduced yet.</td></tr>
<tr><td>Profitability</td><td>▪ Reduced tillage with lower machinery and labour costs.
▪ Less herbicides particularly residuals although this is offset by vine problems in GCTB.
▪ Less cultivation/levelling required rectifying eroded fields.</td><td>Certainty - high – well established in wet tropics with 97 per cent of the crop harvested green in 2007.</td></tr>
<tr><td>Water quality</td><td>▪ Reduced soil erosion and therefore particulate phosphorus in runoff water
▪ Less herbicide use particularly residuals</td><td>Certainty - high – less erosion, particulate phosphorus and residual herbicides.</td></tr>
<tr><td>Requirements for implementation</td><td colspan="2">▪ Fertiliser applicator with coulters or coulter/tine combination capable of subsurface application within or beside the cane row.
▪ High clearance over-the-row spray equipment particularly for vine control; contractors are available.</td></tr>
<tr><td>Supporting information</td><td colspan="2">▪ Hurney A.P., Schroeder B.L. (2012). Does prolonged green cane trash retention influence nitrogen requirements of the sugarcane crop in the wet tropics? Proceedings of the Australian Society of Sugar Cane Technologists, 34, (USB)
▪ Prove B, Truong P, Evans D (1986). Strategies for controlling caneland erosion in the wet tropical coast of Queensland. Proceedings of the Australian Society of Sugar Cane Technologists, 8, 77-84.
▪ Ridge D.R., Hurney A.P., Chandler K.L. (1979) Trash disposal after green cane harvesting. Proceedings of the Australian Society of Sugar Cane Technologists 1, 89-93.
▪ Robertson F.A., Thorburn P.J. (2000) Trash management-Consequences for soil carbon and nitrogen. Proceedings of the Australian Society of Sugar Cane Technologists 22, 225-229.</td></tr>
</table>

	▪ Robertson F.A., Thorburn P.J. (2007) Management of sugarcane harvest residues: consequences for soil carbon and nitrogen. Australian Journal of Soil Research 45, 13-23. ▪ Salter B, Schroeder B, Perna J (2010) Farming systems and their effect on the response of sugarcane to nitrogen. Proceedings of the Australian Society of Sugar Cane Technologists 32, 210-220. ▪ Schroeder B, Panitz J, Linedale T, Whiteing C, Callow B, Samson P, Hurney A, Calcino D, Allsopp P (2009). SmartCane harvesting and ratoon management. BSES Limited Technical Publication TE09004. ▪ Staff of BSES/DPI (1984). A review of results of trials with trash management for soil conservation. Proceedings of the Australian Society of Sugar Cane Technologists, 6,101-106. ▪ Wood A.W. (1986). Green cane trash management in the Herbert Valley. Preliminary results and research priorities Proceedings of the Australian Society of Sugar Cane Technologists, 8, 85–94. ▪ Wood A.W. (1991) Management of crop residues following green harvesting of sugarcane in north Queensland. Soil and Tillage Research 20, 69-85.

Issue - Cropping systems		
Practice 2 – End of Fallow Legume and Weed Management		
Description	Spray out legumes and also problem weeds and vines before they seed.	
Agronomic benefits	▪ Release of nitrogen from legumes is slowed when killed by chemical spray resulting in a reduction in potential leaching losses. ▪ Reduction in the weed seedbank and weed pressure throughout the crop cycle. ▪ Delays introduction of cultivation equipment into the paddock reducing window of opportunity for erosion. ▪ Reduced potential for cultivation at inappropriate moisture content creating large lumps resulting in excessive cultivation. ▪ Allows timely access to the paddock after rainfall as the ground is still firm.	
Profitability	▪ Less nitrogen loss from legumes and less fertiliser N inputs for the plant crop. ▪ Less herbicide in subsequent crops. ▪ Reduced cultivation costs and potential for erosion.	**Certainty -** medium
Water quality	No early flush of legume N into the system. Less overall herbicide use.	**Certainty** ▪ Low: N

	Reduced potential for soil erosion.	▪ Medium – high: chemicals ▪ Low: erosion
Requirements for implementation	Required equipment is available on most farms.	
Supporting information	▪ Hurney A, Schroeder B, Calcino D, Allsopp P (2008). SmartCane fallow and land management. BSES Limited Technical Publication TE08009. ▪ Garside AL, Bell M (2006). Sugar Yield Decline Joint Venture Phase 2 (July 1999 – June 2006). Final report, SRDC, Project JVD002. ▪ Van Grieken M.E., Webster A.J., Coggan A, Thorburn P, Biggs J 2010. Agricultural management practices for water quality improvement in the Great Barrier Reef Catchments. CSIRO: Water for a Healthy Country National Research Flagship.	

Issue - Cropping systems		
Practice 3 – Maintain ground cover during a fallow		
Description	Spray out of old ratoons with a non-residual chemical combined with either ▪ retention of GCTB with/without direct drilled cover crop; or ▪ zonal tillage plus cover crop; or ▪ full cultivation plus cover crop. Where cultivation is employed, the focus should be on minimum cultivation to limit adverse effects on soil structure, biology and organic matter.	
Agronomic benefits	▪ Maintaining ground cover during fallow results in less soil erosion. ▪ Effective killing of old ratoon stubble using chemical spray-out is essential to break the sugarcane monoculture and improve soil health.	
Profitability	Less cultivation/levelling required repairing eroded fields. Plant crop yields increased following a fallow relative to plough out/replant (PORP).	**Certainty -** high to low depending on the degree of cultivation
Water quality	Reduced soil erosion should result in less off-site movement of	**Certainty -** high to low depending on the degree

	chemicals and phosphorus.	of cultivation
Requirements for implementation	Most growers have the required equipment or can hire equipment/contractors.	
Supporting information	▪ Garside A.L., Bell M (2006). Sugar Yield Decline Joint Venture Phase 2 (July 1999 – June 2006). Final report, SRDC, Project JVD002. ▪ Hogarth D.M., Allsopp P (2000). Manual of cane growing. BSES, Indooroopilly, Australia. ▪ Hurney A, Schroeder B, Calcino D, Allsopp P (2008). SmartCane fallow and land management. BSES Limited Technical Publication TE08009. ▪ Prove B.G., Truong PN, Evans D.S. (1986). Strategies for controlling caneland erosion in the wet tropical coast of Queensland. Proceedings of the Australian Society for Sugar Cane Technologists 8, 77-84. ▪ Staff of BSES/DPI (1984). A review of results of trials with trash management for soil conservation. Proceedings of the Australian Society for Sugar Cane Technologists 6,101-106.	

Issue – Soil and water management		
Practice 4 – Reduced tillage		
Description	Reducing the number of tillage operations to prepare ground for planting. This can be a reduction in the number of "conventional" cultivations or by zonal tillage where only the row area is cultivated.	
Agronomic benefits	▪ Less tillage ▪ Improved soil structure and infiltration ▪ Reduced risk of erosion	
Profitability	▪ Less time/tillage ▪ Less tractor operations	**Certainty -** medium
Water quality	Reduction in sediment and chemical loss	**Certainty -** low-medium
Requirements for implementation	Current tillage equipment for reduced tillage. New or modified equipment for zonal tillage.	
Supporting information	▪ Calcino D, Schroeder B, Hurney A, Allsopp P (2008). SmartCane plant cane establishment and management. BSES Limited Technical Publication TE08010. ▪ Garside A.L., Bell M (2006). Sugar Yield Decline Joint Venture Phase 2 (July 1999 – June 2006). Final report, SRDC, Project JVD002. ▪ Hogarth D.M., Allsopp P (2000). Manual of cane growing. BSES, Indooroopilly, Australia.	

	▪ Hurney A, Schroeder B, Calcino D, Allsopp P (2008). SmartCane fallow and land management. BSES Limited Technical Publication TE08009.

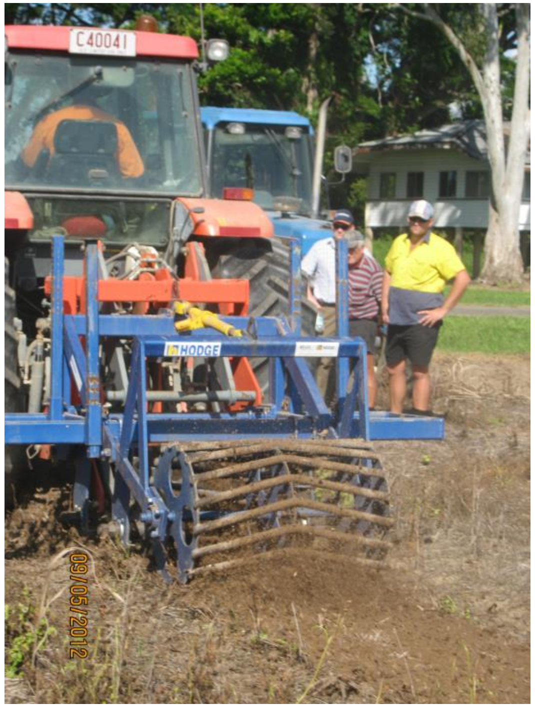
Austil zero-till legume planter

Issue – Soil and water management	
Practice 5 – Drainage maintenance	
Description	Surface drainage – land levelling to remove depressions and pondage areas; lower and re-grass headlands to improve surface runoff and sediment trapping efficiency; conversion of deep square drains to grassed spoon drains where applicable. Subsurface drainage – open drain maintenance and revegetation to enhance water removal and minimise sediment loads. Maintenance of existing subsurface drainage pipes to maintain efficiency and install new systems where required.

Agronomic benefits	▪ Reduced waterlogging effect resulting in better crop growth ▪ More effective nutrient use, ▪ Reduced greenhouse gas losses	
Profitability	▪ Increased crop yield. ▪ Reduces losses of N (both applied and mineralised) due to denitrification	**Certainty -** high
Water quality	Reduced sediment, nutrient and chemical loads	**Certainty -** low - medium
Requirements for implementation	Most growers either have equipment or can hire contractors.	
Supporting information	▪ Allen D.E., Kingston G, Rennenberg H, Dalal R.C., Schmidt S (2010). Effect of nitrogen fertilizer management and waterlogging on nitrous oxide emission from subtropical sugarcane soils. Agriculture, Ecosystems & Environment, 136, 209-217. ▪ Carluer N,, Tournebize J, Gouy V, Margoum C, Vincent B, Gril JJ (2011. Role of buffer zones in controlling pesticides fluxes to surface waters. Procedia Environmental Sciences, 9 , 21 – 26. ▪ Hogarth D.M., Allsopp P (2000). Manual of cane growing. BSES, Indooroopilly, Australia. ▪ Hurney A, Schroeder B, Calcino D, Allsopp P (2008). SmartCane fallow and land management. BSES Limited Technical Publication TE08009. ▪ McKergow L.A., Prosser I.P., Greyson, R.B., Heiner D (2004). Performance of grass and rainforest riparian buffers in the wet tropics, Far North Queensland 2 Water Quality. Australian Journal of Soil Research, 42, 485-98. ▪ Prosser I, Karssies L (2001). Designing filter strips to trap sediment and attached nutrient, River and Riparian Land Management technical guideline. Land and Water Australia, Canberra. ▪ Reghenzani J.R., Roth C.H. (2006). Best practice surface drainage for low-lying sugarcane lands Herbert district. BSES Limited Technical Publication TE 6004. ▪ Roth C.H., Visser F (2003). Quantifying and managing sources of sediments and nutrients in low-lying canelands. CSIRO Land and Water, Technical Report 52/03.	

Issue – Soil and water management		
Practice 6 – Minimum tillage planting		
Description	Minimum tillage planting using a double disc opener planter (DDOP) on wide row spacing to minimise soil disturbance and subsequent tillage operations. Land preparation uses reduced tillage principles. Cane can be planted into a) raised beds formed pre-fallow b) into a level / slightly mounded soil surface c) into a level / slightly mounded soil surface with final bed /mound profile formed post-germination.	
Agronomic benefits/problems	▪ Improved soil structure through less tillage and machinery operations ▪ Opportunity for earlier planting ▪ Less compaction with wider row spacing particularly if it matches machinery row spacing Planting system (a) or (b) above can result in shallow anchorage depth of the sugarcane sett/stool in the soil resulting in increased propensity to lodge and tip stools. This can result in loss of the cane stool resulting in gaps and loss of yield as well as affecting ratoon longevity. It can also result in increased weed growth because of the gappy stand of cane. Problem with high cane rates with billet planters into small space behind the DDO and subsequent soil/sett contact affecting germination. Yield improvements over conventional systems have been difficult to assess to date.	
Profitability	▪ Less tractor operations, tillage and time. ▪ Greater yield potential if earlier planting is achieved	**Certainty -** unknown until farmers get the system correct
Water quality	Potentially slightly lower erosion loss than conventional row spacing in ratoons Less herbicide use as less tillage to stimulate weed growth.	**Certainty –** unknown; trials needed
Requirements for implementation	DDOP capability. Adjustment of all farm machinery used in the crop to suit selected row spacing. Use of a GPS is useful to control machinery traffic.	
Addendum	DDOP plus mounds or hills can be used for any row spacing.	
Supporting information	Calcino D, Schroeder B, Hurney A, Allsopp P (2008). SmartCane plant cane establishment and management. BSES Limited Technical Publication TE08010. Garside A.L., Watters T.S., Berthelsen J.E., Sing N.J., Robotham B.G., Bell M.J. (2004). Comparisons between conventional	

	and alternative sugarcane farming systems which incorporate permanent beds, minimum tillage, controlled traffic and legume fallows. Proceedings of the Australian Society for Sugar Cane Technologists 26 (CD-ROM). Garside A.L., Bell M (2006). Sugar Yield Decline Joint Venture Phase 2 (July 1999 – June 2006). Final report, SRDC, Project JVD002. Hogarth D.M., Allsopp P (2000). Manual of cane growing. BSES, Indooroopilly, Australia. Hurney A.P. and Skocaj D.M. (2010). Assessment and possible adaption of the double-disc opener planter technique in the wet tropics. Proceedings of the Australian Society for Sugar Cane Technologists, 32, 110-118. Garside A.L., Bell M.J., Robotham B.J. (2009).Row spacing and planting density effects on the growth and yield of sugarcane. 2. Strategies for the adoption of controlled traffic. Crop and Pasture Science, 60, 544 – 554. Halpin N.V., Cameron T, Russo P.F. (2008). Economic Evaluation of Precision Controlled Traffic Farming in the Australian Sugar Industry: A Case Study of an Early Adopter. Proceedings of the Conference of the Australian Society of Sugar Cane Technologists, 30,64-70. Tullberg J.N., Zeibarth L.J., Yuxia L (2001). Traffic and Tillage effects on run off. Australian Journal of Soil Research, 39, 249-57. Poggio M, Morris E, Reid N, DiBella L (2007). Grower group case study on new farming practices in the Herbert. Proceedings of the Conference of the Australian Society of Sugar Cane Technologists, 29, 64-70.



Wavy disc cultivator

Issue – Nutrient management	
Practice 7 – Nutrient rate and application	
Description	Adopt nutrient application strategies as outlined in the SIX EASY STEPS principles and guidelines for the wet tropics. This can be achieved as follows: ▪ Determine nutrient requirements and rate for individual blocks based on soil analysis data. These should be adjusted for nutrient inputs from other sources (legumes, mill mud). ▪ Develop nutrient management plan (NMP) for individual blocks and property ▪ Calibrate equipment to ensure correct rate will be applied ▪ Apply fertiliser in the growing zone either sub-surface or incorporated soon after application.

Agronomic benefits	▪ Nutrient inputs matched to crop requirements. ▪ Applying fertiliser in the root zone ensures more efficient and effective crop use. ▪ Sub-surface placement eliminates runoff and volatilisation losses.	
Profitability	▪ Similar to previous grower nutrient management practices under the prevailing environmental conditions. ▪ Productivity and profitability will be reduced at N rates lower than SIX EASY STEPS guidelines.	**Certainty -** medium - high
Water quality	▪ Potential for lower N losses where inputs have been reduced under the SIX EASY STEPS guidelines. ▪ P losses will be dependent on sediment losses.	**Certainty -** medium - high
Requirements for implementation	Fertiliser applicators suitable for sub-surface application either within or beside the row under a GCTB and also in plant cane.	
Supporting information	▪ Calcino D, Schroeder B, Hurney A, Allsopp P (2008). SmartCane plant cane establishment and management. BSES Limited Technical Publication TE08010. ▪ Schroeder B, Wood A, Moody P, Stewart R, Panitz J, Benn J (2007). Soil-specific nutrient management guidelines for sugarcane production in the Johnstone catchment. BSES Limited Technical Publication TE07001. ▪ Schroeder B, Wood A, Hurney A, Panitz J Calcino D (2008). Accelerating the adoption of best-practice nutrient management: Wet Tropics. Short course manual, BSES Limited, Bundaberg. ▪ Schroeder B, Hurney A, Wood A, Moody P, Calcino D, Cameron T (2009a). Alternative nitrogen management strategies for sugarcane production in Australia: The essence of what they mean. Proceedings of the Conference of the Australian Society of Sugar Cane Technologists 31, 93-103. ▪ Schroeder B, Panitz J, Linedale T, Whiteing C, Callow B, Samson P, Hurney A, Calcino D, Allsopp P (2009b). SmartCane harvesting and ratoon management. BSES Limited Technical Publication TE09004. ▪ Schroeder B, Wood A, Park G, Panitz J, Stewart R (2009c). Validating the 'Six Easy Steps' nutrient guidelines in the Johnstone catchment. Proceedings of the Conference of the Australian Society of Sugar Cane Technologists 31, 117-185. ▪ Skocaj D, Hurney A, Schroeder BL (2012). Validating the 'Six Easy Steps' nitrogen guidelines in the wet tropics. Proceedings of the Conference of the Australian Society of Sugar Cane Technologists 34, (USB). ▪ Schroeder B.L., Wood A.W., Moody P.W., Bell M.J., Garside A.L. (2005). Nitrogen fertiliser guidelines in perspective. Proceedings of the Australian Society of Sugar Cane Technologists.,27: 291-304 ▪ Schroeder B.L., Wood A.W., Sefton M, Hurney A.P., Skocaj D.M., Stainlay T, Moody P.W. (20105). District Yield Potential: An appropriate basis for Nitrogen guidelines for sugarcane production. Proceedings of the Australian Society of Sugar Cane Technologists.,32: 193	

Issue – Nutrient management		
Practice 8 – Timing, placement and rainfall		
Description	Adopt nutrient application strategies as outlined in the SIX EASY STEPS principles and guidelines for the wet tropics. This can be achieved as follows: ▪ Sub-surface fertiliser application ▪ Timing application so that a crop is present to begin utilising the fertiliser. ▪ Avoid fertiliser application when forecasts are for imminent rainfall sufficient to cause run-off events.	
Agronomic benefits	▪ Applying fertiliser sub-surface in the root zone ensures more efficient and effective crop use. ▪ Sub-surface placement eliminates runoff and volatilisation losses.	
Profitability	Good placement and timing ensures crop yield is not compromised.	**Certainty -** medium - high
Water quality	Sub-surface placement, timing application to enhance nutrient uptake and avoiding high rainfall events will minimise nutrient losses.	**Certainty -** medium-high
Requirements for implementation	▪ Fertiliser applicators suitable for sub-surface application either within or beside the row under a GCTB and also in plant cane. ▪ Access to real-time weather forecasts including rainfall probabilities and amounts.	
Supporting information	▪ Calcino D, Schroeder B, Hurney A, Allsopp P (2008). SmartCane plant cane establishment and management. BSES Limited Technical Publication TE08010. ▪ Schroeder B, Wood A, Moody P, Stewart R, Panitz J, Benn J (2007). Soil-specific nutrient management guidelines for sugarcane production in the Johnstone catchment. BSES Limited Technical Publication TE07001. ▪ Schroeder B, Wood A, Hurney A, Panitz J, Calcino D (2008). Accelerating the adoption of best-practice nutrient management: Wet Tropics. Short course manual, BSES Limited, Bundaberg. ▪ Schroeder B, Hurney A, Wood A, Moody P, Calcino D, Cameron T (2009a). Alternative nitrogen management strategies for sugarcane production in Australia: The essence of what they mean. Proceedings of the Conference of the Australian Society of Sugar Cane Technologists 31, 93-103. ▪ Schroeder B, Panitz J, Linedale T, Whiteing C, Callow B, Samson P, Hurney A, Calcino D, Allsopp P (2009b). SmartCane harvesting and ratoon management. BSES Limited Technical Publication TE09004. ▪ Schroeder B, Wood A, Park G, Panitz J, Stewart R (2009c). Validating the 'Six Easy Steps' nutrient guidelines in the Johnstone catchment. Proceedings of the Conference of the Australian Society of Sugar Cane Technologists 31, 117-185. ▪ Skocaj D, Hurney A, Schroeder B.L. (2012). Validating the 'Six Easy Steps' nitrogen guidelines in the wet tropics.	

	Proceedings of the Conference of the Australian Society of Sugar Cane Technologists 34, (USB).

Issue – Weed management		
Practice 9 – Weed control accuracy, application, timing and evaluation		
Description	The accurate application of chemicals by applying the planned rate in the correct location and timing. ▪ Correct rate is achieved by using correct nozzles and pressure and calibrating correctly. ▪ Correct location is achieved by matching equipment to row widths so that application can be in the correct zone for broadcast, directed, banded or inter-row operations. ▪ Timing is based on application with respect to weed pressure, crop stage and ability to incorporate through rainfall. ▪ Timing is also to avoid application when heavy rainfall sufficient to cause run-off is predicted. ▪ Evaluation is an on-going process to monitor weed status and control program requirements and efficacy.	
Agronomic benefits	Ensures effective weed control with no crop loss due to weed competition or spray damage.	
Profitability	Less herbicide costs as minimises wastage and includes cheaper alternatives as appropriate	**Certainty –** medium - high
Water quality	More accurate placement and rate of herbicide should lead to a reduced risk of offsite movement	**Certainty –** medium - high
Requirements for implementation	Weed Management Plan. Spray equipment with correct nozzle & pressure setup for broadcast, directed, banded and shields for inter-row.	
Supporting information	Callow B, Fillols E, Wilcox T (2010). Weed Management Manual. BSES Limited Technical publication MN10004. Hurney A, Schroeder B, Calcino D, Allsopp P (2008). SmartCane fallow and land management. BSES Limited Technical Publication TE08009. Masters B, Rohde K, Gurner N, Reid D (2012) Reducing the risk of herbicide runoff in sugarcane farming through controlled traffic and early-banded application. Agriculture, Ecosystems and Environment (Article accepted) O'Grady T, Sluggett R (2000). Herbicide Manual. Bureau of Sugar Experiment Stations, Indooroopilly. Silburn D.M., Foley J.L., and deVoil R.C. (2011). Managing runoff of herbicides under rainfall and furrow irrigation with wheel traffic and banded spraying. Agriculture, Ecosystems and Environment. (Article in press). Van Grieken M.E., Webster A.J., Coggan A, Thorburn P, Biggs J (2010). Agricultural Management Practices for Water Quality Improvement in the Great Barrier Reef Catchments. CSIRO: Water for a Healthy Country National Research	

	Flagship.

Issue – Weed management		
Practice 10 – Focus on weed control in fallow and plant cane		
Description	High weed pressure in the crop is perpetuated by poor weed control during the fallow. If weeds are not allowed to grow and set seed during the fallow, this makes weed control less of a problem in subsequent crops. This can be enhanced by a follow-up weed control program in the plant crop. The bare soil enables a wider choice of control options from cultivation to a selection of residual herbicides.	
Agronomic benefits	▪ Specific problem weeds can be targeted and future populations reduced ▪ Better weed control in the plant crop particularly in initial 12 weeks after planting enhancing yield ▪ Increased options for chemicals will lower probability of weeds developing resistance ▪ Less residual chemicals required in GCTB ratoons	
Profitability	▪ Improved yields due to better weed control ▪ Lower chemic costs due to less chemicals and potential to use cheaper non-selective herbicides like glyphosate	**Certainty -** medium - high
Water quality	Reduction in residual chemical use should result in reduced risk of offsite movement	**Certainty -** medium - high
Requirements for implementation	Most growers have required equipment	
Supporting information	▪ Callow B, Fillols E, Wilcox T (2010). Weed Management Manual. BSES Limited Technical publication MN10004. ▪ Hurney A, Schroeder B, Calcino D, Allsopp P (2008). SmartCane fallow and land management. BSES Limited Technical Publication TE08009. ▪ Masters B, Rohde K, Gurner N, Reid D (2012) Reducing the risk of herbicide runoff in sugarcane farming through controlled traffic and early-banded application. Agriculture, Ecosystems and Environment (Article accepted) ▪ O'Grady T, Sluggett R (2000). Herbicide Manual. Bureau of Sugar Experiment Stations, Indooroopilly. ▪ Silburn D.M., Foley J.L., and deVoil R.C. (2011). Managing runoff of herbicides under rainfall and furrow irrigation with wheel traffic and banded spraying. Agriculture, Ecosystems and Environment. (Article in press). ▪ Van Grieken M.E., Webster A.J., Coggan A, Thorburn P, Biggs J (2010). Agricultural Management Practices for Water Quality Improvement in the Great Barrier Reef Catchments. CSIRO: Water for a Healthy Country National	

	Research Flagship.

Issue – Weed management		
Practice 11– Upgrade herbicide equipment		
Description	Use of improved technologies such as: ▪ nozzles suitable for the job ▪ flow rate controllers ▪ shielded sprayers etc	
Agronomic benefits	▪ Improved weed control due to more effective coverage ▪ Enhanced control of rate ▪ Potentially improved weed control	
Profitability	Purchase costs will be offset by better weed control and less chemical wastage.	**Certainty -** unknown
Water quality	▪ Shielded sprayers allow use of contact herbicides for use in-crop ▪ Improved control will lead to less weed pressure and chemical use ▪ More targeted weed control should lead to less offsite losses	**Certainty -** low – medium; trials needed
Requirements for implementation	New equipment and training in its use.	
Supporting information	▪ Callow B, Fillols E, Wilcox T (2010). Weed Management Manual. BSES Limited Technical publication MN10004. ▪ O'Grady T, Sluggett R (2000). Herbicide Manual. Bureau of Sugar Experiment Stations, Indooroopilly. ▪ Schroeder B, Panitz J, Linedale T, Whiteing C, Callow B, Samson P, Hurney A, Calcino D, Allsopp P (2009). SmartCane harvesting and ratoon management. BSES Limited Technical Publication TE09004.	

Chapter 7 – Extension, knowledge and fostering practice uptake – the next steps

7.1 Extension – a critical element for improved practices

This compilation provides a set of regional summary products that are useful inputs to further adoption by farmers of more profitable and sustainable practices.

During the conduct of the project the team consistently found the demand for facts, figures and practice options high among farmers and their various support organisations. In a period when the Government and the broader community is increasingly focused on improved on-farm practices for Reef outcomes, a strategic approach to providing such information to farmers is considered by many as essential and needs to include a range of activities to cover the various learning styles and demands of the industry. Many in discussions observed that it is somewhat of a contradiction to this high demand to observe the current reduction in investment and capability in extension support to the sugar industry.

Following are a series of observations on extension, developed during the project. These may contribute to and build on the sugar industry's desires to continually improve profitability and sustainability.

Imperative and a major investment priority: Many noted that an increase in extension activities was imperative. Some of the confounding issues that will need to be addressed in any strategic investment include:

- ***resources*** – such as the share of costs across farming and milling sectors, the levels and proportions of public and farmer investment and the need for extension investment to continue into the long term
- ***roles*** – such as the opportunity for private providers and how private and public providers can best deliver a total service to the industry
- ***capacity*** – building the skills and a whole new generation of extension officers, many of whom will require suitable training/mentoring
- ***farmer orientation*** - especially recognising that 1:1 extension is essential as much of the improvements in practice will require detailed assessment of opportunities and constraints [biophysical, social and economic] farm by farm
- ***multiple approaches*** – recognising the multiplicity of learning styles and needs. For example, grower demonstrations can provide particularly powerful messages, especially when incorporated with Participatory Action Learning *activities.*

Better targeted to smart practices: As demonstrated in this compendium, there is a suite of practice options known as "cropping systems" that address profitability and sustainability across soil and water, nutrient and weed management. Certainly such integrated approaches appear to be cost effective. At the same time there is a need to focus on each of these components and the focus on each component will vary with farmer need, farm type and region. Most importantly, all extension will need to ensure the focus on the dual end points of profitability and sustainability is not lost. Practices will only be adopted and will continue to be implemented if they are profitable, the labour is available and the equipment is suitable.

Quantifying profitability and sustainability dividends in partnership with farmers: In the compilation of these practices it was extremely difficult to assign high levels of certainty, let alone specific quantifiable measures for both profitability and sustainability dividends of implementing a particular practice. For example it is relatively simple to say "match fertiliser to crop needs" and assume from a profitability perspective less fertiliser applied is less input costs. Likewise, from a sustainability perspective, if virtually all fertiliser is taken up by the plant then it is easy to assume losses off-farm will be minimal. But what are the precise numbers? Why should I as a cane farmer change my practices if the dividends cannot be quantified? Much needs to be done on this issue. Quantification will need to be done regionally and even then accommodate for variations between farms and paddocks. It is suggested the best approach might be to initiate a major information collection program in strong partnership with multiple farmers already employing these smart practices in each region. The experiences of farmers and the lessons learnt from their implementation of smart practices will be an invaluable addition to the quantification of profitability and sustainability dividends.

Key components of an extension initiative: A checklist of components in any extension initiative would include:

- ***capturing and analysing real time electronic derived data*** – using systems such as *Ag Dat* or the *HRIC Green Sheet* working closely with farmers and downloading and analysing their electronic records as part of the information inputs and the continuous improvement and fine tuning of practices
- ***non-electronic data capture systems*** – not all farmers have the equipment nor the capability to participate in "high end" electronic data capture and analysis systems, so a second tier system would complement the electronic systems
- ***fostering cropping systems and precision agriculture*** – giving preference to systems approaches is likely to yield substantial dividends, especially for the farmers both capable and with paddock sizes to suit such integrated approaches
- ***providing single issue support services*** – as with electronic systems, not all farmers have the capability or desire to rapidly change their farming system. It is equally valid for a farmer to concentrate issue by issue on upgrading their practices – be it soil and water, nutrients or weeds
- ***weather services*** – timing is everything for both profitability and sustainability outcomes. Ensuring farmers have available the Bureau of Meteorology multi-week forecasts and their interpretation in terms of implications for practices would be a very useful input to the tactical within crop decisions farmers make from week to week

- ***whole farming systems approach*** – a farm is more than a crop. Extension is more than the traditional biophysically orientated approach. There are multiple social and economic concerns in any farming business. A whole of enterprise approach is to be encouraged
- ***soil health*** – much of the Reef Water Quality Program's focus has been on soil erosion. Soil health goes across physical, biological and chemical attributes. Improved understanding of how various practices can contribute to overall soil health and thence profitability and sustainability dividends is the next important step in soil management
- ***water and catchment health*** – water quality is certainly a key part of sustainability and the focus on fostering improved water quality leaving farm should continue. At the same time water quantity and overall catchment health concepts could be introduced into extension services. Water use systems design from smart drainage systems to reduce the peakiness of runoff events through to irrigation water efficiency to reduce deep drainage will deliver sustainability dividends for the creeks and rivers across the catchments as well as profitability dividends on farm.
- ***estuary and wetland repair*** – the interface between farm and tidal areas requires a re-think in all regions. Weeds, drains and deoxygenated "black water" dominate many of the interface areas. Repair of tidal systems will kill the freshwater weeds. Recycling and reuse of tailwater will ensure improved water use and water quality. Benefits off farm will be increased estuary productivity – fish, crabs and prawns
- ***nutrient systems*** – there is a need to take a more holistic approach to nutrients across issues such as timing, application rates, positioning, links to soil condition, fallows and legumes. Topics like mill mud application and slow release fertiliser opportunities are still areas of research need in some regions. The farmer orientated decision process embodied in "6 easy steps" provides an excellent model for further development and delivery
- ***weed management systems*** – increasingly farmers are seeking an integrated weed management approach. Chemicals are expensive. Focusing more on the outcomes of weed management for increased productivity and profitability rather than which chemical does what job is essential
- ***fostering innovation*** – Initiatives like *Project Catalyst* provide examples of how best to engage the "top end" of the industry, encouraging on-farm experimentation and partnering research skills with farmer know-how
- ***focusing on expediting adoption*** – most farmers are within the group that will observe and analyse experiments and innovations to determine what practice when proven will best work with their farm and economic conditions. Much of the extension activity will need to focus on these farmers and their particular needs as they progressively adopt improved practices. This is more than one visit or a field day – it's about partnerships, trust, conversations, relationships, sharing of skills and feedback over time
- ***partnerships with researchers*** – practice improvements for both profitability and sustainability emanate from both on-farm learnings and more traditional research trials. Stronger partnerships and two-way flows are essential
- ***minimum quality assured standards*** – all extension services need to be of high standard. Business decisions cannot be made lightly and without quality assured evidence of their benefits
- ***principles and practice options, not prescriptions*** – Generalisations are not appropriate when dealing with a variety of biophysical, social and economic conditions. Equally

importantly, prescriptions do not facilitate responsible, adaptive and flexible decision making

- ***demand driven and adaptive extension services*** – part of the farmer feedback of previous extension services has been their varied relevance to farmer information needs. Farmers are certainly seeking a more multi-disciplinary approach such as cropping systems while still needing to receive high quality technical support in specific areas such as using spray gear and GPS systems to their full capability. Regular review of extension services and fine tuning of investments and activities to meet farmer demand is essential.

Fallow crop - Burdekin

7.2 Knowledge – an overview of R&D priorities

In the conduct of this project numerous knowledge gaps were identified that are constraining the uptake of improved practices for both profitability and sustainability dividends. Following is a list of some of these:

- ***quantifying profitability dividends of practice options*** – more precise knowledge of the relative benefits of various practices is essential and would provide a sound basis for a farmer to select that option that best suits his /her biophysical, social and economic position
- ***quantifying sustainability dividends of practice options*** – as with profitability, more precise knowledge of the relative benefits of various practices is essential and would provide a sound basis for a farmer to select that option that best suits his /her biophysical, social and economic position and motivation
- ***nutrient systems*** – mill mud is part of the practice options in all four regions (Mackay Whitsunday, Herbert, Wet tropics, and Burdekin), however, only the Mackay Whitsunday

region has the GPS tracking of where mill mud has been applied. Likewise the role of slow release fertiliser is yet to be fully explored.

- ***irrigation systems*** – use and reuse systems require further research. For example, much of the tail water entering the Barratta Creek system in the Burdekin flows into the estuarine environment, fosters aquatic weed growth and reduces water quality. Smarter water use systems incorporating strategic, planned reuse systems would benefit both farmers and the environment.
- ***climate forecasting*** – the Bureau of Meteorology is proving up its dynamical model based multi-week forecasting. Already forecast skill is high two and sometimes three to four weeks in advance. Further investment in both forecasting and the application of the forecasting to on-farm tactical activities would benefit the sugar industry, timing being an essential part of the effectiveness of nutrient and chemical applications and of course the implications for export off the farm. Other benefits such as in assisting the scheduling of harvesting are also substantial.
- ***farming systems approaches*** – More and more farmers are looking for integrated practices. For example, some such as green cane trash blanket are well proven in benefit in rain-fed regions, yet provide significant challenges in high yielding furrow irrigation sugarcane farming systems such as in the Burdekin region. Other cropping systems such as GPS guidance aligned to all aspects of farm activities – planting, spraying, nutrient application, harvesting and fallowing are being incorporated by larger farming entities, although for most smaller farmers are yet to gain significant traction. Certainly, some benefits such as reduced stool damage during harvesting are well demonstrated but the total application benefits are yet to be quantified. There is also the issue of small paddock and variable layouts. How best can GPS systems be applied to these conditions?
- ***farming and catchment health*** – The landscape scale issues of catchment hydrology, deep drainage, interface with estuarine and marine ecosystems, fisheries productivity, terrestrial biodiversity, wetlands and riparian health and how best can the sugar industry contribute to these highly valued community assets is worthy of further exploration.

There is no prioritisation in the above list. All are regarded as of high priority. Further analysis would be required to determine precisely where return on investment in R&D was highest for both profitability and sustainability.

For example, it might also be pertinent to think through a change in the research investment delivery model. Much of the R&D investment from all investors is piecemeal, generally three-year projects at say $300 000 per project, spread across multiple organisations, at most tactical in outputs and often with very patchy outcomes. The questions could be:

i) what knowledge will transform tropical agriculture and have flow on benefits across Australian agriculture?

ii) what time and investment pattern is required to translate research outputs into Reef water quality and agricultural profitability joint outcomes?

Perhaps one single major integrated initiative to prove up and make cost effective and practical nutrient management systems - especially systems based on legumes and slow release fertiliser would deliver a higher return on investment. As an estimate of the size of such an investment, think perhaps of say $8–15 million across all the cropping industries and dairy in Great Barrier Reef catchments over say four to five years in strong partnership with the fertiliser industry and co-investment from Rural Industry Research and Development Corporations. This would target an outcome of markedly improved practice where fertiliser inputs and types are matched to plant needs and climate conditions with the consequent huge reduction of N losses to the Reef.

7.3 Expediting adoption rates—the case for further incentives

Much has been achieved through Reef Rescue 1 and those responsible for its implementation are thinking through what the next investment might need to entail. Two areas of potential investment became apparent during the conduct of this project if there is to be continued focused investment on expediting adoption rates of improved practices:-

Consolidation of skills – Reef Rescue 1 has led to a substantial investment in GPS-controlled systems, variable rate fertiliser boxes, variable rate and more precise spray rigs, as well as irrigation recycle pits and associated water re-use infrastructure. Generally investment has been accompanied by farm plans. But how are the farmers tracking? Are they using this equipment to its full capability? Based on their experiences is it time to revise their farm plans? Change their paddock layout? Revise their practices? Improve their monitoring? Review their business model? And so on.

Recycle pit - Burdekin

Recycle pit - Burdekin

1:1 high quality technically competent and multi-objective extension services across farming business to foster their thinking and actions towards further increased profitability and sustainability practices is warranted. This has been discussed previously in the Extension section and would definitely assist in an outcome of maximising the return on Reef Rescue 1 investment at the farm scale.

Broadening the base – Reef Rescue 1 in the last couple of rounds of incentives has generally been over-subscribed. This is because the second cohort of farmers, after the early adopters are now seeing the benefits of the scheme, their earlier suspicions have dissolved and these farmers are now applying for funding. Continuing the incentives program with precise targets in terms of area of land in at least "B" practice and with consistency in approach across the NRM regions will deliver further huge gains in profitability and sustainability. This would consolidate the outcome sought of a high percentage of lands across all GBR catchments in at least "B" practices.

Whatever the funding scheme might be, certainly most of the sugar industry is well motivated to improve practices for the dual outcomes of profitability and sustainability. Capitalising on this motivation is essential.

Chapter 8 – Concluding comments and acknowledgements

8.1 Building the next quantum leap forward in productivity and sustainability

Much has been achieved in practice improvement across the Australian sugar industry in the last 10 years delivering on both profitability and sustainability outcomes. Many organisations and their researchers together with farmers from all regions have played significant roles in this innovation. Most recently, Reef Rescue has catalysed marked increased rate of adoption of improved practices across all Great Barrier Reef sugar growing areas. Project Catalyst has also played a significant role, especially by resourcing farmers to trial various innovations in partnership with technical expertise, again provided from across multiple organisations.

This compendium has capitalised on all these activities and the marked increased understanding of what constitutes profitable and sustainable practices. This compendium provides detail of smart practices at just one point in time. Practices will continue to improve. Farmers will continue to trial and innovate and be ably supported by various organisations.

What is difficult to predict is at what rate these improvements will occur. The secondary and enabling question is - how can continuous improvement be best fostered and resourced? Findings from the research and water quality monitoring components of Reef Rescue are yet to be available. Suffice it to say, there is likely to be continued demands for even more improvement in water quality export from both rural and urban landscapes.

If there is to be a further quantum leap in practice improvements to meet this water quality demand then many of the lessons learnt in the past 10 years of innovation are equally pertinent. Most importantly, we suggest further investment is likely to be most effective through farmer led innovation – providing multi-disciplinary support and expertise to farmer led trials. We also suggest there must be critical mass and focus – investment of a sufficient size and concentrating on key issues, while recognising regional differences. Profitability and sustainability drivers to improve will remain. It is up to all involved with the sugar cane industry to continue collaborating for the benefit of both the industry and the wider community.

8.2 Consultation and contributions

Many people provided thoughts, technical input and discussions as this project progressed. This list, at the risk of being incomplete, acknowledges the support and contribution of these many people committed to a more profitable and sustainable sugar industry in tropical Queensland.

Name	Organisation
Steering group	Jean Erbacher John Bennett Gabriel Crowley with strong support from the entire Reef Protection

	Unit (now Reef Water Quality) team
Matt Kealley Kerry Latter Debra Burden, Vince Papale, Mindi McNiven John Eden Peter Sheedy	CANEGROWERS (Brisbane) CANEGROWERS (Mackay) CANEGROWERS (Burdekin) CANEGROWERS (Mackay) CANEGROWERS (Herbert) and other CANEGROWERS staff in their various offices
Stephen Ryan	Australian Cane Farmers Association
Bernard Schroeder Marian Davis	BSES
Katrina McArthur Kev McCosker Rob Milla	Previously DEEDI – now Department of Agriculture Fisheries and Forestry (DAFF)
Jim Crane	AMCS
Peter McDonnell John Markley	Farmacist
Paul Villis	Burdekin Productivity Services
Phil Moody Chris Chin	Previously DERM, now Environment and Heritage Protection
Neil Sing John Reghenzani Clare Rodgers Rob Coco Will Higham Phil Trendell	NRM groups – Terrain, Burdekin Dry Tropics, Reef Catchments
Peter Larsen	Sucrogen
Burn Ashburner, Colin Creighton, Lawrence DiBella, Alan Hurney and Evan Shannon	Project team